# Introduction to Video Clip Transcript Compilation From NASA JSC Apollo Conference, Lunar Landing Projects Office, December 9, 2008

Adobe Acrobat 9 Reader is required to view the embedded video clips on either Mac or PC computers. It can be downloaded free from: **http://get.adobe.com/reader/** The video clips are Flash files, these clips can be viewed by clicking the movie icon at the end of each clip transcription, it will play in a floating window that can be moved and sized to allow reading of the text, and listening and watching the conference participants all simultaneously. The video controls are at the bottom of each clip with start, stop, and a scroll bar. Right click the video and select full screen or close the floating window.[1]

These clips total approximately 75 minutes of the 7 3/4 hours of videotapes taken of the conference and are designed to give viewers a useful summary of the key issues discussed. The total footage was distributed on 5 DVDs by NASA and the "In Times" and disc number are listed for each clip after the file name headers for each transcription for those interested in capturing more of the conversations before or after those included here.
A separate DVD is included that can be played in any DVD player (requiring no computer), with “Play All” and with selective chapters or clips.

Appendix A: Commentary by Dr. David R. Scott, Apollo 15 Commander (Notes A through P referred in Comments)
The comments at the end of each transcript clip on the following pages are identified by the initials of C. Wayne Ottinger (CWO) and Dr. David R. Scott (DRS).

Appendix B: Transcripts of the Introductory Videos of the Six Apollo Landings is included, furnished by Ken Glover and Eric Jones:
Apollo Lunar Surface Journal, **http://www.hq.nasa.gov/alsj**
Working on the Moon: Lessons from Apollo, **http://www.workingonthemoon.com**

The purpose for this compilation is to assist in the current and future designers to intelligently apply the Apollo experiences to future programs and hear the inputs from those four "moon walkers" in attendance:

1. Neil Armstrong; Apollo 11 Commander
2. John Young; Apollo 16 Commander
3. Gene Cernan; Apollo 17 Commander (also representing Dave Scott; Apollo 15 Commander and Dick Gordon; Apollo 12 Command Pilot, Apollo 15 Backup Commander, and Apollo 18 (cancelled) Commander
4. Harrison (Jack) Schmitt; Apollo 17 LM Pilot and Apollo 15 Backup LM Pilot

This compilation and the "Comments" at the end of each transcription was prepared by Wayne Ottinger, NASA DFRC SAGES Consultant: NASA FRC Lunar Landing Research Vehicle Project Engineer and Bell Aerosystems Lunar Landing Training Vehicle Technical Director

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[1] Top of Page 14, Reset Button clip, right click & clip will run, no controls, to stop, choose disable content (the only clip that could not be embedded as flash file).

**neil new lltv safer** (1 min 33 sec) (In Point at 1 hour 13 min 23 sec of NASA Tape 2)

**Neil Armstrong:** I envy the technology now available, the simulation could be worlds better than it was forty years ago, and that's great, we should take advantage of that, you will, I know. The LLTV if made today I would hope is an order of magnitude better in both performance and reliability so on than it was in our time. Should be and it will make a big difference and it's your job to sort through all these options and come up with something you can afford to do and that will provide that level of confidence on the parts of the crew when they get there. I feel pretty good that you have a process going that will go through this and hopefully come to a conclusion that gives you the confidence that they will feel very comfortable when they are on final up there, like this is just like what I am used to, and I think you can do that.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Don't assume the Apollo LLTV safety record is a reason to avoid another LLTV.
**[1] DRS Comment:** However, one must avoid the 2nd stage effect (see Note A) and the emerging tendency to include: (a) Mars landing capability (Note B); and (b) automation and robotics (Note C).

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**gene risk here not on the moon** (0 min 42 sec) (In Point at 1 hour 15 min 09 sec of NASA Tape 1, Disc 2)

**Gene Cernan:** and all the crew source training and management, I'd expect what Jack and I did in the simulator against up anybody working together problem solving in dynamic simulator environment condition, you don't have time, you can't get that, you don't need to get that on a quote LLTV. I heard things about risk, you know John said we'd crash two or three more before we got to the moon on Apollo 20, maybe he's right, I don't know. I'd rather put myself in that risk environment here to give myself the confidence that I can handle it in the same risk environment, its worth it. I don't want to put him in it with me.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Little Risk vs. Big Risk
**[2] DRS Comment:** The LLTV risk environment on Earth is far less than the lunar lander (LM) risk environment at the Moon. In the Earth environment, the situation is under better control, and it is shorter term with a simpler vehicle. And at the Moon, both the mission and the crew are at risk – a risk that can be reduced by having a qualified and proficient pilot at the controls. Only an LLTV-type vehicle that very closely replicates the LM can provide the qualification and capability necessary for a successful lunar landing (Note D).

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**Gene do all you can** (1 min 15 sec) (In Point at 1 hour 05 min 23 sec of NASA Tape 2)

**Gene Cernan:** This helicopter last thing came potentially closer, but I think if you had the ability to go …, I'm not even talking about cost, but the ability to go one step closer to the real world, you ought to take it. It's too important of a trip. You've got too much at risk; you've got too much hanging out there. You ought to do as much as you possibly can within the earth environment to simulate the real world as you possibly can. Within your confines of cost and risk and however else you want to put all of them in a pot to evaluate.
**John Kelly:** Cost aside, the gimbaled jet vehicle is the most analogous to the job. That's where our team landed.
**Gene Cernan:** Say you're dealing, and I want to complement you for what you're doing to look at all these concepts and for me it's been a very educational day. But you're dealing in a world of technology, which is eons ahead, this world of digital technology is eons ahead of where we were forty years ago. Take advantage of it.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** The LLTV is the closest to the real world as you can get here on the earth for training.
**[3] DRS Comment:** Agree. The LLTV configuration and controllability (handing qualities) are absolutely unique and tailored to replicate the same on the LM (Note E). It is unlikely any other flight vehicle, modified or not (currently known to the industry) can perform the same function.

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**Scorch – lltv too risky** (2:00 min) (In Point at 1 hour 36 min 47 sec of NASA Tape 1, Disc 2)

**Kathy Laurini:** We're going to have a lot better understanding of what the landing site looks like, and maybe some navigation aids on site to get us in there, right. So, we ought to factor that in …
**Charles Hobaugh (Scorch):** So what you are saying Kathy, I agree, but what is your interpretation of what this says? Does this mean the LLTV was too risky to use or does this mean it was important to use it to understand how to fly it? I am troubled that this can be misinterpreted.
**Kathy Laurini:** For me, it's about their describing the experience that they felt in landing the lander. Their problem was …, I don't think they had the information that we will have about the landing site so I interpret Neil's comments is for him getting the visual on the site and the lay of the land was incredibly important because there was a limited amount of information on what the site looked like in advanced.
**Gene Cernan:** And you're dealing with the fourth dimension of time, which no one seems to talk about at once, but you don't have a lot of time to change your mind, you've got to make the right decision the first time and your visual cues are so important. I know that Dave [Scott] strongly feels the way Neil and I feel about this, so when he says zig zag even if you said I don't want to land here, I want to land over there, you are going to make a nice smooth, it's just like flying an airplane, you don't yank it over, you're just going to fly over, and so, I don't know exactly what he was …
**Neil Armstrong:** I don't either, but I don't take it literally, I think what he was trying to say it's kind of a difficult task.
**Wayne Ottinger:** Neil, I think you were quoted as saying, on a scale of one to ten, the landing was a thirteen.
**Gene Cernan:** Made easier though with a little training.
**Charles Hobaugh (Scorch):** I just don't want it to be interpreted in a way that it says the training is too high risk to be able to perform the mission.
**Kathy Laurini:** No. No, No

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Training risk is imperative to minimizing mission risk and ejection seats work well here, not on the moon.
**[4] DRS Comment**. See [2] above.

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**john young no lltv, crashes** (0 min 13 sec) (In Point at 09 min 48 sec of NASA Tape 1, Disc 2)

**John Young:** I think you're making a big mistake just having the LLTV; we crashed three out of four of them. You're going to crash four out four, if we'd had 18, 19, and 20, we would have crashed four out four of them and I think you don't want to build an LLTV …

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** "Apollo crashed 3 out of 4" [was 5 as there were two LLRV's].
**[4] DRS Comment:** The actual LLTV flight record must be analyzed before such a comment is made. As an analogy, not unlike fighter squadrons in the 50's, upon the introduction of a new flying machine, problems occur, often-serious problems. Thereafter, based on experience and maturity of the flight vehicle, the pilots, and maintenance, the problems diminish significantly (Note F). The LLTV is typical – after 4 years of introduction with 3 losses, during the following about 3 years (1 year overlap), LLTV #3 flew 286 flights without loss, through the end of the program (Note G). Thus the comment that "we crashed three out of four" is not a proper assessment, especially for a program that matured and concluded at a high point of success.

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**neil response to young on tv crashes** (0 min 19 sec) (In Point at 10 min 03 sec of NASA Tape 1, Disc 2)

**Gene Cernan:** I was next in line to crash.
**Neil Armstrong:** Look at the details at each of those crashes; we should easily be able to avoid those.
**John Young:** What do you need an LLTV for, the simulator will tell you everything you need to know.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Flight test culture not transferred to training, 3 of 3 safe VTOL ejections extraordinary.
**[5] DRS Comment:** Regarding crashes, see [4] above. Regarding the need for an LLTV, see Note D.

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**Industry capability now vs Apollo** (3 min 9 sec) (In Point at 1 hour 37 min 05 sec of NASA Tape 2)

**Charles Hobaugh (Scorch):** The thing that scares me though in your time frame, that was the third space vehicle in design in rapid fashion, we haven't built anything but a bunch of paper slides in a long, long time. One benefit of the F-35 coming along is that at one point they were enough competing companies that they were all seriously considering design of VTOL type systems and how they were going to integrate thrust vectoring, stability and control and different components that, maybe that will help us, but we don't have the corporate knowledge in the generation we're in, you know, building a new vehicle, a new aircraft one type per year coming off the production line [old generations], we have stagnate industry [now] and that kind of scares me. We may be up here, [motioning high with hand], but building real hardware we're down [motioning low, hand on table].
**Nils Larson:** The F-35 is still in development, it has come a long way, but development takes forever, that's why I'd say you need to start the RV sooner than later, because it will take awhile. Great stuff, but it's going to take awhile.
**Gene Cernan:** Don't underestimate the industry, but that's one reason why you guys, all you guys and gals, you really need to keep your nose involved in what their designing if you're going to stretch your budget and training. Doesn't make any difference, you really need sometimes to be a pain in the butt, you know I are an engineer when I graduated from Purdue, but I didn't know how to spell it, ok, and you're going to use this, or those who follow in your footsteps are going to use it, you owe it to them to make sure that they've got what they need to get the job done, not what someone thinks they need. And I say that in all reverence to, I'm an engineer too, so I can say that, but sometimes engineers come up with great ideas but when you put them in the cockpit you can't reach them, you can't touch them, they don't play together or one thing or another, well you guys are responsible to make sure they do. If there was one thing that made a difference, Neil's involvement in the LLRV determined that we were trained for the rest of all lunar flights. An a testimonial to the work he did and everyone else did, everyone, think about this, everyone we sent to the moon, including Apollo 13, came home to talk about it. I'm not discounting Apollo 1, but every flight we sent to the moon came back, and that's a testimonial to that industry you're talking about, it can be done, but there is a lot of people that have to make their worth known.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Apollo's industry partnership and astronaut participation in the design/development needs to be repeated today and the industry capability today needs to be carefully focused on specific tasks early.
**[5] DRS Comment**: See [1] above. Also, the pilot must be part of the overall process of design, test, and evaluation, including especially in human factors as well as procedures development and verification.

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**gene simple cost effective** (1 min 49 sec) (In Point at 1 hour 07 min 05 sec of NASA Tape 2)

**Gene Cernan:** But I want to go back to what I said, I don't know if you all were here this morning, going to the moon: from time you lift off to the time you complete that landing, it's a necessary evil, it's fun, it's a challenge, you'll do it if you get a chance, but it's a necessary evil, the idea in today's world of going to the moon is being there, being there. So make the trip from the beginning to touchdown as safe and as simple and as uncomplicated and as cost effective as you can possibly make it and take all that talent and all that technology and put it to work on the moon. Put it to work where it counts. Going; what did we do to occupy our time, oh you'll find things for those three days, we'll do some experiments, we'll do a few of them, but you know what, we did them because we had the time to do them, not because they were really part of the program… Neil's major objective was to get on the moon and get home safely. When we got back down to Apollo 17 is get on the moon, make use of your time while you were there. We threw the technology of lunar rover on the moon, gave us tremendous capability, all we did was build on the same technology that Neil used to get there. We didn't change anything, we didn't change a thing. Oh the LM was a little bit heavier lift capability and one thing or another, we took the tools we needed to do something special when we got there. So I really emphasize, just think simple and safe, that will automatically make you cost effective, I think, and will get the job and…

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Don't re-invent the wheel, we've trained before with the sixties technology, we can certainly do it again with new technology.
**[6] DRS Comment:** See [1] above. Remember also to design to the mission (landing) "techniques" that were developed during Apollo, not just "procedures" (which are system sensitive), but the methods by which a human pilot can manipulate a machine to a successful landing on the Moon (or wherever) within a limited amount of time, fuel, and visibility.

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**gene fill the gap and keep it simple** (1 min 35 sec) (In Point at 1 hour 24 min 6 sec of NASA Tape 2)
**Gene Cernan:** We probably could have made the job easy today if we all said we don't need a flying device. We don't need it; let's go straight from the simulator to the moon. That would have made your job easy. I think what you heard today is we strongly support some free-flying device, helicopter, LLTV, kite with a string; I don't care what it is, you figure it out. You heard what we thought. I hope you come out of this meeting with the fact that based upon our experience; we feel a free-flying device is extremely valuable in our training to get us to the moon. I mean I hope you come out with that too.

**Kathy Laurini:** Definitely, and free-flying device that does not meet the end-to-end totality of requirements, a free-flying device that has certain characteristics.
**Gene Cernan:** You figure out what it is, you know we told you what we thought based upon what we had available, which was obviously adequate and go from there. But I do hope you come to the conclusion that you need to fill the gap, maybe there is a couple of other things allow you to fill the gap between a T-38 or a simulator and the moon. Maybe it's a little helicopter, maybe it's some other kind of device and maybe it's eventually something…, but I keep saying don't get too sophisticated, stay simple, you don't have to re-create the world here on earth just to go to the moon.
PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Why re-invent the 'wheel", just use today's technology to make a better gimbaled jet.
**[7] DRS Comment:** Again, see [1] above.

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**schmitt manual ldgs** (0 min 21 sec) (In Point at 0 hour 58 min 10 sec of NASA Tape 1, Disc 2)
**Harrison Schmitt:** I think this is a very important thing, one reason why chances are that you'll have manual landing is because you can start your manual landing in a controlled situation, not an uncontrolled situation. You need to bear that in mind, it's not really on your list, but it's an important point that's been made several times.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Apollo astronauts had to insist on manual landings, the logic is still valid today.
**[8] DRS Comment:** "Manual" landing actually means "pilot-in-the-loop." We called these manual landings because the pilot was controlling the vehicle manually (by hand) – but in actuality, the hand-controller inputs were going through the computer, which itself could have landed the LM automatically (albeit never used). Being in the loop provides more than just a good feeling (which it definitely does) – being physically in the control loop has several operational benefits: (a) the pilot is tuned, or on top of the situation, -- if a failure occurs during an auto land, the pilot must recognize (accept) the failure and instantly insert himself into the control loop; which requires a finite amount of time; and (b) being in the loop at the time of a failure removes the ambiguity of determining whether or not an indication of a failure is actually a failure of

the system or a failure of the indicator (see Note H).

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**Why an Early LLRV** (1 min 21 sec) (In Point at 1 hour 35 min 47 sec of NASA Tape 2)

**Neil Armstrong:** I think the thing that strikes me is how big an advantage you have over what we had forty years ago, how little we knew when we started the LLRV. We were stability and control guys and we did a lot of dead stick landings, kind of landings were our world, boy, we could do all kinds of landings, but -- stick force per G and PB over 2V [and L/D versus speed], and all those things we used, none of them fit, we didn't know anything about that, you know so much more now than we did, so, you are starting from such a high plateau that what you have left to go seems miniscule compared to what we had to face.

**Kathy Laurini:** I agree with you, and that's what I struggle with an early start on an LLRV, you know. What for? What for is the question and that is where I think the information you're [Ottinger] going to provide to Michelle [Rucker] will help us get at our risk so we can …

**Wayne Ottinger:** Yeah, we will be able to match those up I think.

**Kathy Laurini:** Are there things that an LLRV can help us with that are aligned with the things that are keeping us up at night.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Kathy -- Did the LLRV really contribute significantly to the LM design/development and help answer the question and that's what I struggle with an early start on an LLRV, you know….What for?

**[9] DRS Comment:** (1) Handling qualities; (2) the control requirements of coupled vertical thrust with lateral-directional thrust, unique in the annals of flying machines (see Not E); (3) pilot interfaces – instruments and controllers (hand, switches, buttons, etc.); and (4) designing proper thrust-to-mass rations (e.g. Altair RCS thrusters seem to low for the mass, especially for adequate handling with both ascent/descent and ascent-alone configurations. (Also see Matranga memos, email, June 5, 2009)

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**neil kathy early studies fall off the table** (2 min 3 sec) (In Point at 1 hour 19 min 59 sec of NASA Tape 2)

**Neil Armstrong:** I don't know if there is a way for you to afford to get some preliminary work done on whatever configuration you choose, you can't get the money to build it right now or buy it, but you can get some studies done to give you a little more meat to work with.

**John Kelly:** We are starting to suggest some things.

**Kathy Laurini:** But my sense is to, following on the point that Mash [James Dutton, Jr.] made, but we have a very constrained budget in the next couple of years and so what I will struggle with is what are investments that you can make now to help make decisions in the future that you won't regret because you made them too soon as you don't understand the task because you don't understand the approach profile because you don't understand a number of things. So, there are some big items hanging out visa vie our design, our concept of the vehicle that make me say that this one may be at risk because if I go down this direction, this investment may be at risk because if I go down that direction you know this data, I don't need it anymore. So, trying to find the investments that are affordable in these next two years that are extremely cost effective and that you are sure that the investment will be useful in future decision making, are the challenges that we have at this point in time.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Don't wait for the last pieces to fall into place, the Apollo experiences already provide adequate information to make the investment in a free flight simulator to test ALHAT components and systems while simultaneously giving insight to vehicle control system and pilot interface concerns in a proven high fidelity environment.

**[10] DRS Comment:** Studies to define and confirm flight techniques. Also see [9] above.

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**Ottinger ddt&e** (2 min 0 sec) (In Point at 1 hour 33 min 44 sec of NASA Tape 2)

**Gene Cernan:** I can tell you talking to Dave Scott and Dick Gordon; they feel strongly very much the way we feel.
**John Kelly:** Actually, Dick and Dave's comments are in the report; I would encourage people to read those if they have other inputs.
**Kathy Laurini:** OK, let me take the opportunity to go around the room and see whether anyone else has a question or a comment or something that they heard that they just are dying to follow-up on.
**Wayne Ottinger:** I'll take the chance, I just want to re-emphasize the fact that we did have an early start, we beat the LM design with our LLRV design and flying, got it started and we did contribute a lot to Grumman on their design with DDT&E [Design, Development, Test, and Evaluation] with the LLRV. I'm following up with Michelle's [Rucker] request yesterday to offer you some documentation from the sixties that will more definitively define that, but I just want to encourage you to keep in mind the earlier we can get started on DDT&E with a new LLRV that will help reduce the risk on the DDT&E of the trainer and the Altair itself, it will really payoff as a return on investment and you don't want to delay it for any reason to get crammed in to like we were in certain situations in Apollo where we made some sacrifices because we lacked support like funding, schedules were compressed and we were always under the pressure and Neil can speak to that with his having to give up the bulk of his training until a month before he launched.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Altair today has adequate input from Apollo and ALHAT to initiate a study to provide budget and schedule data for a free flight gimbaled jet that can provide a significant return on investment with early DDT&E support for Altair and a new LLTV.
**[11] DRS Comment:** See [9] and [10] above.

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**Apollo LLTV Started Too Late** (0 min 49 sec) (In Point at I hour 45 min 30 sec of NASA Tape 2)

**Wayne Ottinger:** Back to the early start, In Apollo, we got started in the LLRV, as I said before, before Grumman started the design. Where we screwed up was waiting too long on the training because I remember when it came to getting the trainers kicked off, Bill Geisel [President of Bell Aerosystems, the LLRV/LLTV contractor] up at Bell had to cough up about a million bucks to buy long leads seven months before he ever had a contract with the

trainers. That could translate to, what, twenty million dollars today, what contractor is going to do that today. So, just take some lessons. Get started early because you don't want to get into {Kathy – right) that kind of a box.
**Kathy Laurini:** Ok, That's good.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Early start, properly focused, can provide a significant return on investment.
**[12] DRS Comment:** See [9] and [10] above.

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**I knew it was – been in the tv** (0 min 10 sec) (In Point at 1 hour 01min 08 sec of NASA Tape 1, Disc 2)

**Harrison Schmitt:** You [Cernan] didn't tune me out when your descent rate was sixteen feet per second.
**Gene Cernan:** But I knew it was and I knew what I had to do to stop it, because I had been in the LLTV.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Another testimony to the quality and fidelity of the training in the LLTV.
**[13] DRS Comment:** Another factor is the motion that the pilot feels, especially while maneuvering briskly – and correspondingly a motion that the LMP is not familiar with. That is, unexpected physical motions and forces are distracting, and the pilot in particular must be inherently tuned to this motion (see Note I).

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**gene neil training reactions same** (0 min 36 sec) (In Point at 1 hour 33 min 00 sec of NASA Tape 2)

**Gene Cernan:** I think you've heard a lot about, you know it's amazing, Neil and I even haven't talked about this in forty years, but his thinking and feeling surprisingly enough, and he said a couple of things here today, you know it hits me right, right on the spot exactly. So we did this thirty six – forty years ago and three years apart and sure we were different, but his reactions, responses to his training and his landing were almost identical to mine.
**Kathy Laurini:** Yeah, that's significant.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Another testimony to the quality and fidelity of the training in the LLTV.
**[14] DRS Comment:** This could be considered part of the "zoning" process (Note J) – we all learned to completely focus on the intense and demanding task of landing a vehicle on the moon. We were all trained into essentially the same performance box. As an analogy, we all (most of us) land airplanes in approximately the same manner.

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**Doris Kelly Ottinger decouple** (0 min 56 sec) (In Point at 0 hour 06 min 34 sec of NASA Tape 1, Disk 3)
**Clinton Doris:** I think Gene did a great thing for us earlier when he said sim sim sim … you know if we looked at this from the same perspective, how would you guys -- I don't want you guys to go through the exercise of prioritizing so to speak -- but are there things here that are nice to have versus absolutely necessary from the flight …
**John Kelly:** Well there are general categories and we'll have to consider you know how they have been mapped into a fixed base simulator …
**Clinton Doris:** Gravity offset for instance, how imperative is that?
**John Kelly:** I think I heard earlier that it is pretty important.
**Wayne Ottinger:** Well it's going to affect how long you have to sit there and wait to move a certain distance and you're doing that in a time-critical situation where you're running low on fuel and I would think unless you can de-couple in pitch and roll, you're not doing a great training job.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Without a gimbal for de-couple in pitch and roll, negative training will occur to an unacceptable level due to the large vehicle attitude errors.

**[15] DRS Comment:** Agree with the comment. But even beyond the gimbal, all of the characteristics of the LLTV are mandatory to maximize the probability of success during an actual lunar landing.

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**Apollo Expertise Window Closing** (3 min 34 sec)( In Point at 1 hour 46 min 20 sec of NASA Tape 2)
**Kathy Laurini:** Anything else? Do you, Clinton have any relevant comments?
**Clinton Doris:** Nothing more than just expressing my great gratitude to you guys taking the time, this is exactly what we wanted to try to get out of the meeting and likewise to you guys sitting here, its helped tremendously and I think John this hits our expectations and exceeds it, this is valuable information for us for the future and I think we got the message, I think most of us sitting here agree with the, I don't know about the kite-on-the-string, but absolutely with the fact that we need something and so we'll just have fun doing this figuring out what the something is.
**Gene Cernan:** A in reverse, It's nice to know that's you're still loved and wanted.
**Neil Armstrong:** I don't know about the loved part.
**Gene Cernan:** You know, it won't be long, there's going to be fewer of us here, and if you had waited another five years you may not have as many of us to talk to and another ten years, probably less than that, and God knows in twenty years we'll be looking down from somewhere, I suppose watching what you do (Armstrong – "looking at me"), … blabbering and slobbering, no seriously, to be able at least to give you our opinion, do with it what you want, other than a strong support for what you're doing I personally don't have a dog in this fight and I just want to see you be successful and if what we say taints your opinion one way or the other, use it in a manner in which you want, like I say from a technological point of view and the capability that you have surrounded yourself with these kind of people, you are a winner, you can't lose and don't think we're absolutely right, just say …, on the other hand this is not a history of simulation, this is a history of six successful lunar landings and so someone's got to say they did something right.
**Kathy Laurini:** You give us a tremendous gift in making our job easier by having done it all those years ago and you continue to give by your willingness to interact with us as we try to re-do it in this day and age and solve the same problems with new technology in a different time, so we're really grateful to you for taking your time to be here, and I would go so

far to say loved, I'm a woman so I can …
**Gene Cernan:** [to Neil Armstrong] Are you going to be here in ten years? I'll tell you what, if you're here in ten years, I'll be here in ten years. You were first on the moon, all I did is follow in your footsteps so that' the way its going to be from here on out. [Gene and Neil clasping hands].
**Wayne Ottinger:** I hope Gene is absolutely right about the timing and how long their going to be around, but I just want to share with you that out of a number of key people we're losing them at three or four a year on this program, either Alzheimer's or death and the sense of urgency on me is, it's very urgent to capture and get all this feedback as early as we can.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Take advantage of the time now, before it's too late, to extract as much as you can from the Apollo experience, and apply what you learn intelligently into the new designs.
**[16] DRS Comment:** Agree. But as a caution, stay with the actual experiences and avoid the extrapolated experiences (e.g., those that are emerging from the many post-Apollo studies and reviews that extrapolate, and then extrapolate again from the original written Apollo reports and experiences).

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**altair deck sim** (2 min 42 sec) (In Point at 0 hour 36 min 20 sec of NASA Tape 1 Disc 3)
**Kathy Laurini:** Let me ask a ask a question, you guys saw the height of the deck in the simulator, how does the height of the deck want to drive the implementation of this vehicle? (Gene Cernan --- the what, Kathy?) the height of where you are, you're 6 meters, 8 meters above the surface when you set down. How does that want to drive the geometry or the design of this vehicle, a gimbaled jet vehicle?
**Charles Hobaugh (Scorch):** An interesting thing to bring up is your perception is based on the environment you're used to working with or working under, as much as I hate to say Howard (Law) might have a point on the simulation side, it's one credible thing you get, because if you were to fly a low-level on the East Coast with big pine trees and everything else and then go out to the desert and try to make the sage brush look like pine trees because that's what you're used to visually, you'd be scraping the dirt and so where you actually put yourself height –wise may be a completely different sensation than the real environment as opposed to what you end up with … what you train … I'm not sure you can necessarily mandate that.
**Kathy Laurini:** I'm trying to evaluate, when we start getting evaluation criteria, how important is that in this kind of a vehicle, a lower priority (Scorch – lower priority).
**Jason Cudnick:** I can mention that, Wayne (Ottinger), correct me if I am wrong, the LLTV versus Apollo was about one-third the height difference, (Wayne Ottinger – no about one-half) and in future concepts that are expected to replicate that, about one-half.
**Gene Cernan:** But as I remember, we could look out those LM windows and have a fairly direct view to the surface and we're sitting at the front end of the LLTV and we had the same view down to the surface. You put yourself behind that big old platform out there, you're not going to look this way (pointing straight down), you're going to look out there (pointing way out front) and my thinking is for a training device you'd want to blank out that area, now you've got an aerodynamic problem, …would it be an absolute requirement, probably not, but it sure… more than the dust thing we talked about, for me, it would be nice to know what I'm not going to see, but of course, you get that in the lunar simulator.

**Harrison Schmitt:** That' what I'm wondering, Gene, a thousand hours in AMS (Altair Mission Simulator) if you're not going to have that visually.
**Gene Cernan:** You're right Jack, I think you get most of that in the simulator itself because if you compromise and you put yourself at a higher risk factor if you try to aerodynamically put some kind of shade up, I wouldn't' want to do that, I'd rather train without it.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** If desired, a holographic display could be provided in an LLTV with the deck artificially shown, with a direct view for safety without the internal display.

**[17] DRS Comment:** Within some reasonable limit, the eye position above the touchdown point is insensitive to height. The intended approach is to reach a hover above the touchdown point and descend vertically (null forward and lateral motion). Given the potential of dust up to about 100 feet, the pilot must be prepared to make an IFR landing anyway. The crosspointers were an excellent aid to this, and should be clearly visible and properly located (include them in the LLTV as part of the training, although the LMP can call them out during the landing). Similarly, aircraft pilots seem to be able to transition readily from a fighter to a bomber (or T-38 to a 747)

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**gene 30 ft deck ht ok** (0 min 32 sec) (In Point at 0 hour 24 min 15 sec of NASA Tape 1 Disc 3)

**Gene Cernan:** The thing about being so high in this vehicle, you're just going to have to convert your computer up here to you're actual motion across the ground. The closer to the ground you are, the better you know how fast you're going, left, right, up, down, whatever. The further you are away, the more difficult it is and that 30 feet versus twenty feet is probably going to make a difference, but the guys will get that, they'll get that, they'll see that in the LMS, in the simulator.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Apollo LLTV half the size of the LM, the new LLTV will be half the size of the Altair.

**[18] DRS Comment**: See [17] above.

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**gene neil eye level ht cg accommodation** (2 min 39 sec) (In Point at 0 hr 13 min 12 sec of NASA Tape Mockup Tour)

**Gene Cernan:** … higher, probably knows about much higher than if he flies a 172

**Erisa Hines:** But from you' alls training and perspective, that came from the LLTV?

**Harrison Schmitt:** It's a combination of (Clinton Doris – from a number of things I'm sure) Gene is saying it's a combination of experiences.

**Gene Cernan:** Combination of helicopter, I think helicopter, LLTV, and fixed base simulator – visual.

**Neil Armstrong:** Off-hand, I don't see it to be a problem (Cernan – I don't either) we see that in aviation all the time (Doris – all the time) different kind of vehicles, different cockpit heights, but I might be overlooking something, there might be something I haven't thought about, but off-hand I don't see it as a problem.

**Gene Cernan:** I don't either, it's … I don't want to simplify it, but once you get accustomed to that environment that you are going to be part of you know what to look for, you've been there before, if you're landing thirty feet above… you're touching thirty feet above the surface or five feet above the surface you know what vehicle you're in, you know how it its going to respond.

**Erisa Hines:** But it is how you get that experience before you get there. So I understand your answer (Cernan – all the pieces) yep.

**Gene Cernan:** Visual simulators, I think LLTV, helicopter (Schmitt – LMS is good) LMS , the whole thing, the whole thing.

**Neil Armstrong:** One thing I thought about or experienced, but I think you get this in the process but it's a taller vehicle and I don't know exactly where the cg is and so on, but sometimes the amount of motion that you get at the cockpit is different than the amount that the footpads are seeing by a substantial margin and you have to get a sense of that to know how careful you have to be up on top to make sure the bottom is doing the right thing, but I don't see it as a problem, It's experience and training that will make you…

**Gene Cernan:** Exactly, and as far as the accommodating the distance you are from the surface; it just comes with experience and training.

**Wayne Ottinger:** Our Apollo LLTV was about half the size dimensionally of the LM and our proposed design for a new version LLTV is about half the size of the Altair and I think relatively speaking, if it worked in Apollo we hope it will work in Altair.

**Gene Cernan:** It accommodated the LLTV, you accommodated the LMS, you accommodated the Lunar Module. Harrison Schmitt: The Altair simulator I think gave a good perspective with the television displays and windows and everything that [?] rates as well height above the surface, it was pretty good.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** No need for a thirty-foot high trainer.
**[19] DRS Comment:** See [17] above.

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**gene roger eye level** (1 min 10 sec) (In Point at 0 hour 0 min 0 sec of NASA Tape 2)

**Gene Cernan:** I know that if I pitch ten degrees, I'm going to start moving at some rate that I expect to see. Now, if I'm in the LLTV and the cg is… if I'm standing on the cg up there [Altair] , when I pitch ten degrees, things not going to be the same, OK, they're going to be grossly different. What I'm going to get for what I put in is going to be different, that's all I'm asking, does that make a difference, or not? I want to know what to expect from my inputs.
**John Kelly:** That's a good question, we had the same one, and again if we can incorporate that feeling in there we'll sure try … into the vehicle design.
**Gene Cernan:** And it may be so close, it won't make any difference.
**Harrison Schmitt:** I don't think it's going to be a big deal.
**Roger Zwieg:** That was all incorporated in the STA. Went to great efforts to put it in, put in side-force controllers …built the first two airplanes, flew them once, and took it off, the crews said I can't tell the difference... fly it one way or the other, it doesn't matter. Save money and take them away…
**Neil Armstrong:** I think that's a good point. My sense tells me that it's not going to be important and we can't prove it.
**Charles Hobaugh (Scorch):** The hardest landing we had was one where the commander experienced large side force.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** The crew will adjust for the difference in eye level above the surface.
**[20] DRS Comment:** See [17] above. However, regarding the STA comment, the physical configuration of the LLTV cockpit, especially controls and displays, should be exactly the same (or as close as possible) to that of the lunar lander. A blindfold cockpit check of all controls and displays is mandatory before proceeding to "checkout" in the lunar lander – standard aeroplane practice. Also, in general, caution on comparisons or analogies with other trainers, especially the STA (being a recent example of a unique trainer). See [23] below, and Note P.

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**neil sitting vs standing** (0 min 59 sec) (In Point at 0 hour 02 min 20 sec of NASA Tape 2)

**David B. Jarrett:** One last question here, does it matter if you're seated or standing for the training vehicle?
**Clinton Doris:** If you want an ejection seat it does.
**David B. Jarrett:** No, that's not what I'm talking about (unidentified voice – from a fidelity standpoint)
**Neil Armstrong:** I don't think it is important, the reason I say that is my upper torso was rigid with respect to the visual reference that I was looking through, and from the waist down, what the configuration of my appendages were weren't too important. You know I think I could have done it from a kneeling position or feet out front maybe …
**Charles Hobaugh (Scorch):** Was that kneeling position a pun?
**Kathy Laurini:** That's a good input.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Ejections seats are well worth having.
**[21] DRS Comment:** An ejection seat is mandatory.

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**scorch dynamic motion get the experience important** (2 min 5 secs) (In Point at 1 hour 25 min 42 sec of NASA Tape 2)

**Charles Hobaugh (Scorch):** One last analogy too is when we train repetitively for ascent, you know like we say we spent so much time training to get there, just get into low earth orbit, in this case we spent the majority of our training, probably 60% is depleted in the first 8 minutes of the mission and you've got two weeks left to start and you haven't even practiced that part, so that part is fine, but nothing really prepares you for ascent. You watch the gauges move, you watch things happen, they throw malfunctions at you, throw switches, you do a bunch of crap, but until you get the pumpkin suit on and you're really thrown in the seat and being chunked around on ascent and drive all through this big … it is not an environment that is adequately simulated from the dynamic motion point of view. Entry is a little better when you practice competitive STA runs, you do suited STA runs and you are used to kind of staring down at the pedals and you feel what a 100% speed brake may feel like when you are being pushed forward in your seat and there is vibration from the thrust reversers just like you get a little vibration from the airframe. You feel like you're there, you feel like that's home. When you do it at KSC, that's where you actually land. There is nothing better, that's almost a one to one training environment and that makes it very simple. The other analogy I had was basic carrier training, we were in a time frame when we were just doing two-seat "A" training, AV-8A, and then you get thrown into the AV-8B single seat the first time, I memorized every muscle movement I had to make, but until you get that eye-opening awareness of the acceleration on your body with greater than the one to one thrust to weight, you haven't lived, so you've got to experience that, if there is a way to do it ahead of time, it would just make your job that much simpler.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Another endorsement for a free flyer.
**[22] DRS Comment:** LLTV training time is a much smaller fraction of lunar mission training, so must be available long before launch, and due to the importance of landing, frequent training sessions must be scheduled.

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**gene Mash free flt lltv** (1 min 47 sec) (In Point at 1 hour 15 min 01 sec of NASA Tape 2)
**Gene Cernan:** The question going in today is whether you need to fill the gap between a simulator and the real world. I hope you got the message that it's yes. Which is in [disagreement] with John's statement. John doesn't feel its… but that's his opinion. And John sure has flown a lot of space flights, including the STA and everything else, but would John have liked to flown the shuttle without the STA, (Kathy – he said no), would the shuttle simulator (Scorch no) been enough for you guys to go and fly, well, there is your answer.
**Kathy Laurini:** I think his bias on the LLTV, from what I understood, was the safety one and I he didn't accept the assertion that you could make it safer than the one that you guys flew, so given that assumption, he says for what I get out of it, the risk for me I wouldn't take that trade, I wouldn't recommend going that …
**Charles Hobaugh (Scorch):** I think that in that time frame this was happening in the sixties we were dropping airplanes left and right. I mean new aircraft designs, pushing the edge of the envelope on stuff, they didn't have the …
**Wayne Ottinger:** In the time that we had our three crashes they had several fatalities in the T-38's and lost some helicopters down there.
**Nils Larson:** You two [Mash and Scorch] are the guys that someday might get the call to actually go, across the table, what are your thoughts?
**Charles Hobaugh (Scorch):** I'm too old.
**Nils Larson:** So, Mash, if you're going, what do you want?
**James Dutton, Jr. (Mash):** I think once we knew the task well enough, I think we need to pursue a flying vehicle, and the LLTV seems to be the best option, and I think you can do it better today, but I want to understand the task better….

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Another endorsement for a free flyer and Crew support for an LLTV.
**[23] DRS Comment:** The lunar landing is so unique, that an LLTV type vehicle is essential. Conversely, for the Shuttle approach and landing, if the STA were not available, training in an F-104 or similar low L/D aircraft would be adequate, the profile and judgment requirements are essentially identical, and control responses are similar. No known vehicle, other than the LLTV, can replicate the control responses of the lunar lander (LM) (Note P).

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**brad neil feel thrust crisp rkts** (1 min 29 sec) (In Point at 0 hour 2 min 23 sec of NASA Tape 1 Disc 3)
**Brad Jones:** When we briefed this to the crew office several months ago, one of their key concerns was "where are you feeling the thrust". (Cernan – where are you what?) Where you're feeling the thrust. Is it at the seat of your pants or is it … in a helicopter you know it's in a different location, so I'm wondering where in here is that captured on your (DFRC's trade study) list, or is it?
**John Kelly:** Yeah Brad, I don't think we did actually; maybe it falls generally under motion cues.
**Brad Jones:** I'm also wondering from these gentlemen, if you consider that to be important as well?
**Gene Cernan:** Your feeling of thrust?
**Brad Jones:** Where do feel the thrust, so in the LLTV you've got the gimbaled engine below you as you would on the

actual LM whereas in the helicopter you've got the rotor above your head, so …
**Neil Armstrong:** Generally, the feeling is the same, but the rocket engines typically have a lot faster response than either an aerodynamic surface or a jet engine. So, if you have a rocket engine boost it is very crisp and you notice it instantly when it hits, it doesn't come like this (hand moving slowly upward), it hits you like that (moving fist into open hand) very quickly … so whatever simulation you have you should do your best to try to match as well as you're able what the Altair …
**Wayne Ottinger:** You're not really feeling the gimbaled jet, you're feeing those lift rockets on the outer frame that pitches with you.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** The gimbaled jet is the only concept that can provide the rocket response times to replicate the Altair systems as well as decouple from earth g in both pitch and roll and accurately offset the aero drag forces for the training mission.
**[24] DRS Comment:** Thrust forces are similar – LLTV and LM – vertical by lift rocket, and lateral-directional by RCS. But during a lunar landing, the noticeable thrust is lateral-directional; the vertical thrust while standing and strapped to the floor is low, relatively constant, and not really noticeable. Therefore, the primary LLTV motions and forces are almost identical to the LM.

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**Reset Button & Altair Gimbal RV Sim** (5 min 17 sec) (In Point at 1 hour 40 min 15 sec of NASA Tape 2)
**Kathy Laurini:** Al [Strahan], did you want to say ..
**Al Strahan:** I just wanted to follow-up on something you hit on a minute ago, originally it was like a discriminator between whether or not you needed an LLTV, but it seems to be a discriminator between this gimbaled jet concept and the other two helio concepts and between the gimbaled jet concept and the STA, this idea of the reset button and the fact that this gimbaled jet concept like an LLTV doesn't have it, but all the other ones appear to have it. How important is that, really?
**Gene Cernan:** I used the reset button as just an example, you're in the simulator and you screw up and we screwed up and blew off and landed hard and screwed up malfunctions and one thing or another, and that's what simulators are for and you do it again, again, and again… it's stop, lets go out, have a cup of coffee and talk to the instructor, where did I screw up, how could I have done it better, what did I miss, what did we miss we're a team in there. So when I talk about the reset button, that's what I refer to. But I go back to something to what you [Scorch] said earlier, if you go out in the STA, you've got your plan to shoot ten landings, right. You said a minute ago, which one's, the most important that you prepare for, that you're most focused on, it's the first one, it's your first shot and that's what I'm trying to say, you don't have a reset button in an LLTV, you don't have a reset button in a lunar lander. That's the first landing, its got to be the one you focus on and the fact that you don't have a guy you can … a safety pilot to save your butt, the fact that you can't say, stop the world, I want to talk about this thing I just messed up on, you don't have that, you've got … I mean it's a philosophical thing but you brought it home to me when you said, I'm going up to make ten landings in the STA, but, man, this is the one that's going to count, the first one, that's the one you've got to make happen. And the LLTV puts you in that psychological environment, I'm up here, I've got to make this landing, and ain't anybody else going to make it for me and that's where you are when you're on the moon.
**Al Strahan:** Would that be a discriminator against the Sky Crane and the other helicopter and also the STA then because they do have a safety pilot.
**Gene Cernan:** I'm not against it, all I'm saying is if you want to throw a safety pilot in the system, throw him or her in. I'd be careful, I use the word him generically. If you want to put a safety pilot in the system, put it in, if you can afford it, makes it less risky, that's fine, all I'm saying is you're giving up, you're giving up a valuable part of that simulation and it's the psychological affect of taking you one step closer, by yourself, without mission control, by yourself, one step closer to the real world of landing on the moon, that's all I'm saying. That's me; other people may disagree with me. Put a safety pilot in, fine, you reduce your risk, you gain safety, you spend more money, but you also lose of that what I think is a very valuable part of the LLTV simulation and that's having to do it.
**Wayne Ottinger:** And you could increase mission risk because you did it that way.
**Gene Cernan:** That's the point; I want to take the risk here (Kathy –right). I can get out of screwing up here; I can't get out of screwing up out there.
**Neil Armstrong:** One minor point, this gimbalable engine [Altair], that might have an affect on vehicle motions in such a way that you would want to somehow incorporate that into a simulation, I don't know whether you will or not, but you need to know whether it will or not, so you might go on the track of finding out to what extent it might affect the simulation, and how, so it could be implemented if it was important to do so.

**Gene Cernan:** In all simulations we can freeze time, you can't freeze time in the real world. And the LLTV puts you in quote that real world. Is that valuable? I think it is, you all may have your own opinion of it.
**Al Strahan:** It appears to be a discriminator between these three concepts, that's why I wanted to bring it up.

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**CWO Comment:** The presence of a safety pilot (having the availability of a reset button) removes the valuable psychological component of providing confidence that the pilot can indeed accomplish the mission in the real world.
**[25] DRS Comment:** The LLTV does put you on the line and it forces you the think the lunar landing profile (Note J) – it does not have a reset button such as a simulator, but it does have a breakout capability to exit the lunar sim and then land in a much easier and safer mode. A safety pilot actually increases risk (see Note K).

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**Visual ques for free flyer and psycho vs sim:** (5 min 16 sec) (In Point at 1 hour 41 min 37 sec of NASA Tape 1,Disc 2)
**Howard Law (NASA JSC):** What I do want to go back to is how much this in-flight vehicle if you really want to do this would have to simulate the visual ques because their the drivers on this … to me their the drivers on the psychology cues. If you get to the moon, I'll bet you even money if you flew your LLTV and I got somebody in a ground base simulator and I made the visual ques so realistic that when he got to the moon it looked exactly the way it had looked in the simulator that he would feel really comfortable. So what I am trying to suck out of you guys is how much we have got to do in that in-flight simulator visually to make it like what you got to on the moon and how we don't.
**Neil Armstrong:** Off the cuff, the answer, wouldn't that be great to have the high-res visual and undoubtedly that would make that aspect of the training immensely more valuable than it is now. But, it still misses a lot of things, you don't get the motion, you don't hear the rockets coming from where they're coming and you don't have that feeling.
**Howard Law:** Lets say the magic wand, you know un-obtainium, I can get a sim that has the visual and that feels like your ear, right, and then also shakes you so that when you get to the moon you feel the same visual cues, motion cues and then have a response.
**Harrison Schmitt:** Are you going to blow up the simulator if you make a mistake?
**Gene Cernan:** That's wonderful, get your simulator to that point, but you're not there, you're still within reach of the coffee cup and the freeze button. You are missing a psychological effect, so don't back off from what Neil said, yes it would be nice to have a nice lunar crater in front of me which may be the same one that everyone else trained for for the last four years so its not going to assimilate, I saw my landing site when I pitched over at 7,000 feet. I knew where we were going to land, …..we saw the craters, we had them named, we knew that, but the psychological effect you get is of hanging it all hang out at that moment at that time when you have to perform. And that is what is I said earlier, it doesn't have to replicate the surface. It doesn't have to replicate the control system, but it puts you in an environment, which is as close to hanging it out where it really counts as you could possibly be. And I'll tell you what, I don't think you can substitute any kind of fidelity in the simulator for that, nothing, moving base, noise, visual, add it all together, you're still not, you still just don't have it out there where this is it fellow and I would rather find out about me at Ellington than for the first time landing on the moon.
**Howard Law:** I was trying to get to was, for the in-flight vehicle, the in-flight trainer, how important in its development is it to make sure that its visual cues are going to look like exactly you see when you get to the moon. How important is, for example, to demonstrate the plume and the loss of visibility that is going to come from that last 120 feet. How important is it to have something on the field of view that looks like a crater vs. going to the runway, because I think that is going to drive some of the complexity.
**Charles Hobaugh (Scorch):** Why don't you use that to augment, not to replace?
**John Kelly:** We just saw some technology, some of my team saw a demonstration by Mr. Fox, I don't know his first name … "Jeff" and there is some promise there I think in what they saw, if you guys want to comment on that briefly.
**Nils Larson:** You could assimilate that into a free-flight trainer.
**John Kelly:** Could you have a kind of pass through?
**Gene Cernan:** You can go out to Flagstaff and fly this thing if you want to absorb the cost its going to take to support it out there.
**Wayne Ottinger:** Better than what that is, you said your landing was much like going through the Grand Canyon down at the bottom of the canyon there.
**Gene Cernan:** Your answer to the question is, yes it would be nice, but should it drive the design of the [LLTV]
**Wayne Ottinger:** But you didn't do it on Apollo, you landed on the runway, you did your re-designations easily off the Ellington runway and got used to it.
**Gene Cernan:** I re-designated to a spot, whether it looked like a crater or a piece of concrete I could care less.
**Harrison Schmitt:** You could complicate the landing task in a free flyer without endangering the vehicle or the crew if

you want to. If you want to use it for scoring and things like that you can do it with paint or with non-dangerous objects, but I think these guys are telling you that that's not the critical aspect of a free flyer.  That's a simulator, and the more the better, the higher the fidelity of the simulator the better, there is no question about that.  But you can't reset a free flyer. You can rest a simulator.

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**CWO Comment:** You cannot substitute anything for a free flyer that will fill the gap in the training that is needed.
**[26] DRS Comment:** Agree with Cernan – selecting and flying to a spot on the runway or to a point near a crater on the Moon requires the same skills -- the image is not important, the ability to select and fly to a specific "point" above the surface is.  Relative to dust, the final-final approach is most likely (should be) vertical anyway, so once the vehicle is over the selected point, then with the proper vertical rate, out the window provides only horizontal motion cues anyway and those can be seen on the crosspointers (if they are located properly).  So VFR or IFR, the technique is essentially the same. No need for a special forward simulated cue to look like the Moon.

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**scorch $ should not drive** (0 min 28 sec) (In Point at 1 hour 13 min 24 sec of NASA Tape 1.Disc 2)
**Charles Hobaugh (Scorch):** Money isn't the thing issue we should be talking about right now.  We should talk about what's the right thing to do, what kind of things we need and then the budget has to support…
**Kathy Laurini:** I totally agree, but what I am trying to do is get the requirements to the must have to the importance, this summary was fantastic, what do you guys really think...
**Gene Cernan:** You send me back, that's all I need.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** The best training may not have a significant cost penalty.
**[27] DRS Comment:** But money is a reality and must be a factor in management's analysis.  However, management's responsibility in committing the crew to a landing must also be weighed in the tradeoffs of LLTV cost and risk (Note L – very important).

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**Neil 11 gene psycho** (4 min 30 secs) (In Point at 0 hour 44 min 07 sec of NASA Tape 1, Disc 2)
**Neil Armstrong:** Apollo Eleven's running short on fuel is widely known, and has been widely discussed by the press and others and even in mission control here, people were biting their nails…. I had been flying the machines at Ellington; we took off with nine minutes of jet fuel and someplace between ninety and a hundred seconds of rocket fuel. So we were always landing with twenty, or fifteen or twenty or twenty five or 30 seconds, we had to – and so it wasn't very much of a concern to me in Apollo Eleven because it was just like I was used to and if I made a mistake it would be a bad one. So I think that was a … Dave Scott thinks this was one of the more important aspects and one that I haven't really though much about. He does think that is an important experience to make yourself have the mindset to be comfortable in a short fuel situation.
**Gene Cernan:** Neil says it exactly the way I feel; you know to me its one step closer to the real world.  You are out there at four or five hundred feet, you got five minutes of fuel, fifteen, whatever the hell it is, its only a you and your maker, OK. You're running a problem in an LMS in a simulator, you have a problem, you go topsy into a crater, push the freeze button, lets go on and have a cup of coffee and talk about it.  When you are in the environment Neil is talking about, you don't have a freeze button. You are going to either do it or not do it, and I want to know that I can do it and feel comfortable before I get out there two hundred and fifty thousand miles away and have to do it one time successfully.  I think putting yourself in that environment, quote, a risk environment, you know John [Young] is right, I don't want to crash an LLTV, but I would rather have the option of screwing up here and learning something and getting out of it and doing it again, because I don't have that option when I am landing on the moon.  And so its not … there is a lot of psychological effect to the comfort level I think we gain when were in that real world in a lunar module, landing on the surface of the moon that we gained because of the environment we found ourselves in the LLTV.
**Neil Armstrong:** I mentioned also with regard to your earlier question, you do often change your landing point at some point after – on your final approach and a lot of the guys flying the practice sessions would intentionally change their landing from the place where it was going and make themselves do that.  I grant you, I believe that aspect can be covered

by many of these competing … but it is an important part of training.
**Gene Cernan:** The six-degree of freedom concept simulation you found yourself in ….. I don't find myself in a helicopter in a six-degree of freedom mentality. I just didn't. I'm flying over there, but this one, you could drift over there and if you put intentionally put the drift in as we all did when we got familiar with what we were doing, you had to take it out. And we would pick a spot out there at Ellington to land on and you would force yourself to go in another direction so you have to force yourself to correct. It was the environment that you found yourself in and that you were there alone, you look over your shoulder there was nobody there and you were going to land it or you were going to pull the ejection seat, you are going to do one or the other. And I would rather have that option here because I didn't have it on the surface of the moon.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** In the LLTV, you either do it or eject, good training to build confidence.
**[28] DRS Comment:** The fuel limits were a very valuable contribution to the overall preparation for the LM landing. This limit forced early decisions on the approach and touchdown, which if anticipated gave us time to change the touchdown point during the final gallons of fuel – something to learn based on the actual Apollo 11 experience. This additional limit also helped compensate for time-compression during the actual mission (Note M). Further, having more fuel (time) than actually available during the lunar landing would be negative training; it would preclude the pilot from integrating the time factor into his thinking (Note N).

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**Gene probably is not good enough** (1 min 41 sec) (In Point at 1 hour 08 min 45 sec of NASA Tape 2)
**Gene Cernan:** Think simple and safe, that will automatically make you cost effective I think, it will get the job done. Boy, there is nothing worse than saying you should have been here when kind of a thing, but you know it worked, it worked. And we did something right with the development of the LLTV that allowed us all to get there safely, comfortably. I was comfortable when I landed and I attribute that to the training we had, which goes from the LMS to the helicopters to the LLTV, as I said this morning, could we have done without the LLTV, I'd like to think probably. John said if we flew 18, 19, and 20, wouldn't we have crashed another LLTV? I don't know, I don't think so quite frankly. I don't think so these crashes were mechanical crashes for the most part. If we ran out of LLTV's after Apollo 14, would John and I gone to the moon on 16 and 17? Probably. Would we have made it? Probably. But probably isn't good enough if you can cover your bet, if you can … I would rather … rather than probably I would like to say you bet your sweet bippy we would have made it. The LLTV gave me that confidence, that's all I'm saying (Kathy – "right").

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Cover your bet on the training, do the very best you can.
**[29] DRS Comment:** Without the LLTV, the risk is much higher, especially in the event of other failures or problems that would divert the attention of the pilot from flying the machine and finding a touchdown point – would management be willing to commit to the higher mission risk without the LLTV (Note L)?

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**Complexity of off-nominal tng vs skill tng** (3 min 39 secs) (In Point at 1 hour 07 min 14 sec of NASA Tape 1, Disk 2)
**Kathy Laurini:** I think you know we have to be really careful about it because if I listen to what I am saying and I have the project manager hat on, therefore I have to keep an eye on the money piece of the problem, right. There are a lot of objectives associated with off-nominal events that people want to use this vehicle to train to, there is commonality with the flight system, I am seeing a trainer that is very complex, very expensive and so I think we really ,,, when we get as a group we start getting down that path, let's try to recognize it and then get back onto the objectives because there is a whole …. we will get wrapped up I think in convincing ourselves that we want something that maybe addresses everybody's objectives rather than … we want to find out from you guys what are the objectives.
**Harrison Schmitt:** Kathy, I think what you are hearing from these guys is not a complex vehicle but that a vehicle that allows you to learn how the real vehicle performs. And that is different I think than putting in a whole bunch of safety complexities.
**Kathy Laurini:** But how the real vehicle performs for me is also different than that psychological ability to handle off-nominal situations, right?
**Harrison Schmitt:** But they are not unrelated.
**Kathy Laurini:** Well I can see then. Do you have to train for ....do you have to design your simulator such that you have

got a , I don't know, stuck-on RCS thruster, how where you go in term of identifying the off-nominal situations that you are able to model in the training vehicle, right, and how many of those put you into an unsafe situation.
**Charles Hobaugh (Scorch):** Well, you have even a more fundamental issue to deal with the simulator, and that's to try to stick with what the LLTV and the next generation vehicle the STA [Shuttle Training Aircraft] does, is just trying to handle the nominal event takes enough approaches …. in and of itself before you inject the failure cases. You have to get that one nailed down, you have to understand the basics of how the maneuver is going to work, what kind of sensations you are going to feel if you do a specific input what sensation will you get out of that, what reaction do you expect from the vehicle. You need to make that basically cemented into your brain how that is supposed to work and then from there, the rest of the stuff is you know, failure cases handled in the simulators, you need to fully engrain what the vehicle is going to do, what its going to feel like, what feels right, that is the kind of stuff that you get from a real in-flight simulator.
**Kathy Laurini:** Ok, so let me just summarize so we can move on. What I heard is getting the real feel of flying the vehicle in an atmospheric training vehicle like this is important and some ability to add in a capability to put you in a psychological, in a challenging situation so that you on the stick flying the vehicle have to make these decisions with your bacon on the line is also important, not necessarily every contingency scenario, but some scenarios.
**Neil Armstrong:** You are certainly going to have a simulator to do a lot of those kinds of things and you shouldn't have to duplicate all those kinds of situations in whatever you use as a vehicle for ….
**John Kelly:** We agree in that and Joe Tanner made that point very clear to us, and we agree with it. His basic input was you need to get the muscle memory down of that task. You know it is a skill trainer.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Focus the new LLTV on the training tasks only it can perform, leave the rest to the other simulators.
**[30] DRS Comment:** The purpose of the LLTV is to teach the pilot how to fly, not how to analyze systems that are different from those of the LM – for the LLTV, that's the job of the LLTV flight control team (CRM) (and for the LM, that's the job of the LMP and MCC ). Therefore, absolutely no need or purpose to insert intentional systems failures or simulated failures in the LLTV for training; those would be another aspect of negative training (Note N).

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**cernan on air crane** (1 min 25 sec) (In Point at 1: hour 03 min 57 sec of NASA Tape 2)
**Gene Cernan:** We had a Bell H-13 to train with in Apollo, we transitioned, we learned to fly – I'm not an expert helicopter pilot, but it gave us a little of the vertical environment, but it was far from the fidelity of a lunar landing; and of course, it was just a basic H-13 and had no control system changes. It helped, but I am sure glad I had somewhere else to go prior to landing on the moon. I think it's important though that you explore all these possibilities. This last presentation came closer to me to a potential LLTV trainer, although I don't understand the fidelity or the dynamics of it. I got lost; to be honest with you gentlemen, in the ability to reproduce what a lunar landing might be like if I'm hung under this big sky crane, I lost that. I don't know how that could give me the kind of visual concept, physiological, psychological, concept of what I am looking for to get ready to go to the moon.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Air Crane needs to demonstrate value as a complement to a gimbaled jet.
**[31] DRS Comment:** For many reasons, there is absolutely no substitute for an LLTV-type vehicle – the motion of the LLTV must be uncoupled from any forces other than 1/6 g. This includes aero forces and mechanical linkage forces; otherwise the dynamics of the LLTV and its corresponding controllability change substantially. As an example, the LM landing simulator at Langley was very good, but it had a significant lag in response time, something to which a quick human response was very sensitive – a quick sequential input would get you in trouble, the pilot inputs would be out of sync due to the electrical/mechanical feedback delay. (probably a function of natural frequency, similar to a pogo on landing a T-33).

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**neil on air crane** (1 min 56 sec) (In Point at 0 hour 59 min 30 sec of NASA Tape 2)
**Kathy Laurini:** I would like some general feeling about the other options that were presented today.
**Brent Cobleigh:** Before we get into that, we presented two other concepts, I think we know how you feel about the way you flew it before; we can upgrade that to modern architecture, hopefully safer. We presented two other options here, what are your impressions of those? Can you start with the Sky Crane with the pod underneath?

**Neil Armstrong:** Well, my own reaction is that it's a very clever idea and could provide some useful experiences and perhaps quite a safe and repeatable way. A lot of questions about its fidelity in terms of the actual reaction of the vehicle to control inputs. I think you can certainly roll that cockpit or capsule around underneath, probably match anything you want to do, that part, but the helicopter's motions I don't understand yet how well that could match, I have some suspicions that there are certain things that normal helicopter reactions would prohibit duplicating what you would expect in the Altair. So, but I think it is neat and I don't think it is going to give you the landing experience that I would like, but I'd have to know a bit more about it certainly, but is clever.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Worth a feasibility investigation as part of the continuum of sims, but not as the highest fidelity potential
**[32] DRS Comment:** See [31] above -- For many reasons (e.g., Note D), there is absolutely no substitute for an LLTV-type vehicle.

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**Neil, votes single pilot** (1 min 16 sec) (In Point at 1 hour 52 min 57 sec of NASA Tape 1, Disc 2)
**Neil Armstrong:** I can understand the concept of a two-person … …. so that the guy that's doing the training didn't have to really be able to fly the machine, know the systems real well, all he had to do was do the simulation, and I think there is merit to that concept. It has two disadvantages in my view, one is that it takes away the pucker factor part of the reality of having to do it and the second is, as I visualize it, it would be a far more complicated and expensive vehicle. I think that would be true. It would have the advantages of allowing more efficient use of the Altair pilot's time in getting his landings in perhaps, but I think I come down on the side of the single pilot, will be my personal preference, although I think I understand both concepts.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Get the best concept for psychological benefits and save the money at the same time.
**[33] DRS Comment:** The 2nd pilot issue raises many factors and many concerns -- increased risk, increased cost, reduced flying time for the lander pilot, etc. (Note K).

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**continuum of sims** (2 min 32 secs) (In Point at 1 hour 01 min 26 sec of NASA Tape 2)
**Roger Zwieg:** Can you have more than one, can you have more variable types, can you some of each, do you suppose?
**John Kelly:** Yeah, sure, there could be kind of build-up to a more high-fidelity simulation, but that depends on budget I suppose, but certainly.
**Kathy Laurini:** I think we are going to be challenged to find the most effective continuum of experiences to meet the training requirements that we ultimately come up with, so we will, ….I think Gene said it well in the beginning, you develop your requirements, you can't expect one vehicle to meet all the requirements necessary to prepare for a pilot to land on the moon, for me, I think going through these in detail is going to be interesting because it will help us when we get to the point of deciding, People seem to think helicopter experience is right and so how do we … is a garden variety helicopter adequate or do you really want to get some of these capabilities that were discussed by Bob [LCDR Robert L. Byers, USN, Rotary-Wing Test Pilot Instructor, U.S. Naval Test Pilot School]. these VSS modifications that buy you more in a continuum that is worth the investment?
**Charles Hobaugh (Scorch):** Kathy, that is one thing that just makes the hair on the back of my neck stand straight up, is that thinking that this is a just a helicopter type of mission. It is a much more dynamic operation, helicopters have the luxury of long on-station time, they can hover in close to the ground, a lot of their positioning they do in close [???] with a high come down. You are also talking maneuver extremes in velocities and also your descent rates are much different, so I get very nervous every time when I hear that we are going train the lunar landing purely on a helicopter mentality.
**Kathy Laurini:** But do you think no…
**Charles Hobaugh (Scorch):** I know you haven't said that, but I have heard that said, so if you're not saying that..
**Kathy Laurini:** I think though…I mean I think there is a consensus that some component of helicopter experience is important (Scorch – "can be valuable") can be or (Mash – "as a build up you're saying, you know like ") yes.

**Charles Hobaugh (Scorch):** There is a place for it; there is use for it, but not at the exclusion of a higher fidelity simulator.
**Nils Larson:** So you are saying, have a helicopter for lunar module commanders the same as we have T-38's for shuttle commanders.
**Neil Armstrong:** That's what we did.
**Nils Larson:** In that aspect, I guess you are still going to have an STA-like vehicle to physically train for that last ditch landing, you know that might be (Kathy – "right").

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Continuum of sims, yes, but not to exclude a higher fidelity [free flight] simulator.
**[34] DRS Comment:** For the lunar landing: (1) the LLTV for flight dynamics and handling qualities, and fuel management; (2) a helicopter to familiarize the lander pilot with near-vertical approaches and selecting touchdown points; (3) a "LM" simulator for normal and emergency procedures development and training; and (4) an LLTV fixed-base trainer for LLTV procedures development and training. Also, something like T-38 for general flight proficiency and tuning.

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**neil rate of descent cmd** (1 min 37 sec) (In Point at 1 hour 01 min 56 sec of NASA Tape 1, Disc 2)
**Neil Armstrong:** I want to make a comment here, it's kind of a little detail, but it's kind of important. One significant difference between the lunar module and any training vehicle used to simulate the landing, it [the LM] had an auto throttle and it could control descent rate, it could hold descent rate. Now we couldn't do that in any of the other machines, although in a plain helicopter you can pretty close in keeping a standard descent rate, but that was a wonderful addition, it made the lunar module much easier to fly than any LLTV or helicopter, so I think the point here is that whatever the concept Altair actually is, and I'm sure it should have rate of descent command because that was such an important characteristic to make the handling qualities of the landing good, the training devices, it would be nice if they had that as well. We didn't have that in the LLRV … It was an important function.
**Gene Cernan:** So we sort of, in a sense, with the LLTV trained for a degraded mode (Armstrong --that's true) with a hand-held throttle (Armstrong – with acceleration command).
**Wayne Ottinger:** We had an auto throttle, but it was for the 5/6ths control.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** The next LLTV can easily accommodate an auto throttle on the lift rocket system.
**[35] DRS Comment:** The ROD was great; but still, becoming proficient in the LLTV "manual" landing is most important – for both the potential failure of the ROD as well as to appreciate the ROD function. Another recommendation to reduce the pilot's load in the cockpit is to add a pipper to the LPD grid; that is, a "dot" on the CDR's window that moves along the grid according to the two-digit numerical computer projections of the landing point. This would correspond to (or substitute for) the DSKY numbers being read by the LMP. Any other CDR window display would be superfluous and detract from the visual and mental requirement of selecting and flying to a specific touchdown point (Note O).

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**ottinger flt test culture** (1 min 17 sec) (In Point at 1 hour 54 min 32 sec of NASA Tape 1, Disc 2)
**Charles Hobaugh (Scorch):** Something we haven't touched on that, I don't know if it is relevant or not, but it seems like when you were doing LLTV you worked through like a mission control, that would be something to try to divorce yourself from.
**Neil Armstrong:** It started very small and primitive and grew over time and Wayne probably remembers, maybe others here remember, by the time we had a few losses, then that mission control aspect of it beefed up a good bit and was more effective, no question about it.
**Wayne Ottinger:** I made a statement yesterday morning when we were talking about an early LLRV to do some DDT&E for both the LLTV as well as the Altair, that wherever the training is done we need to really transfer the culture of flight test a lot more effectively to that training operation than what we did in Apollo, because it suffered through two accidents before we got it beefed up to where it needed to be.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Provide adequate schedule and support for the training operations emphasizing a core CRM to protect the pilot/vehicle.

**[36] DRS Comment:** "….try to divorce yourself from…" – NO [nitrous oxide]. The LLTV systems operations and failures are different from the lunar lander – therefore, the pilot need not (should not) be burdened with procedures and systems knowledge that can be handled by the CRM, just as the LMP and MCC handle during the actual landing. If an LLTV systems problem occurs, the pilot is notified to breakout and land asap in the safest mode – the ground can then handle the problem. Attempting to have the LLTV pilot manage the LLTV systems, when the task is to learn to fly, would be negative training (Note N). And the CRM has much better information than a 2nd pilot.

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**ottinger fly at DFRC flt test culture:** (2 min 30 sec) (In Point at 0 hour 27 min 30 sec of NASA Tape 1, Disc 3)

**Harrison Schmitt:** Wasn't the significant part of the failure [LLRV/TV accident] was the change in the weather conditions you were willing to tolerate, for training versus what was done for the development…

**Wayne Ottinger:** It contributed to the culture, yes; we went from 15-knot limit at Edwards to 30 knots out here at Ellington.

**Jason Cudnik:** Also, I think when we talk about operations, something Wayne has harped on is about translating that flight test mind-set from someplace like Dryden to someplace like JSC here and that control room mentality, those operations that we are used to at Dryden, make sure that transfers here to JSC.

**Harrison Schmitt:** Well, as I pointed out, maybe JSC is not the best place…

**Wayne Ottinger:** Well I am going to point that out, and that is if you could get the guys exposed initially up the VMS [NASA Ames] so they get a few flights in the VMS, drop down to Edwards and do your training there and you've got a lot more airspace, it's a lot safer. We could do higher altitudes if we need to.

**John Kelly:** I'll go on the record and say I endorse that idea.

**Charles Hobaugh (Scorch):** What is the high-density altitude at Edwards?

**Neil Armstrong:** Twenty three hundred feet.

**Wayne Ottinger:** It wouldn't affect the TV performance significantly at all, not with the new engines (Chuck Rogers -- not with the new engines) (Harrison Schmitt – what is the altitude at Edwards) twenty three hundred feet (Mash – what were the wind limits) we used fifteen knots, they got it pushed up to thirty [at Ellington]. The thing that killed us at Ellington was that they didn't monitor the wind shear. I know in some of the very low control power research flights we were trying to establish how low could you go on control power and still control it and I can remember getting a deep sea fishing line thing and tying little balloons every 50 feet on it and launching the thing and watching where the wind shear was, because we couldn't really tell with the helicopter that low of a shear we were looking for to make a safe flight in, for the research flights.

**Charles Hobaugh (Scorch):** Sounds like it's not a great vehicle for small shear…

**Wayne Ottinger:** No, in the research mode, where you are really trying to determine how low you can go because were feeding that data into Grumman, because they had to know how low you could go, but then you build some margins on top of that.

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Altair training should hopefully be less demanding than the Apollo launches scheduled every two months. Altair training in both the VMS at ARC and the LLTV at DFRC could be made to work.

**[37] DRS Comment:** Yes, translate DFRC culture to JSC. But remember the big picture – limited training time available; you need to take the mountain to Mohammed -- that is, all of that travel to different places is time consuming, costly, and introduces additional uncertainties in training time available, pilot energy available, and risk. The LLTV training at EFD was almost ideal – it could be achieved with very little pilot overhead, and often scheduled within some training window that unexpectedly opened. Even better would be to have (or move) the LLTV to the Cape for final training. (I think that the flight crews should live at the Cape anyway….!!)

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**cobleigh scorch ottinger crm air cr lltv** (1 min 53 sec) (In Point at 0 hour 29 min 45 sec of NASA Tape 2)

**Brent Cobleigh:** Well, compare this against … a modern version of the gimbaled jet; you have to fund a control room for every single flight.

**Charles Hobaugh (Scorch):** No you don't, if you do this (Air Crane), you might have to fund the same number of people you do also, so it's not to say you're not going to be monitored … or be monitored in the cockpit, what I was trying to get at with the control room concept is that you want to divorce yourself from as much of that as possible, a bare minimum to

get by to safely operate, you don't need to have somebody running your flight.
**<u>Brent Cobleigh:</u>** But in this case the pilot that normally flies this airplane has everything he normally has with really no increase in risk, he is flying this vehicle, but an LLTV, now you've got someone who is training, they may not have all the displays they need to know the engine's not performing properly today or whatever, I think … we've seen as Wayne was talking earlier they did go up in their … you know when we reduced the amount of oversight … [for] an operational trainer versus a research vehicle, that's when we started having accidents.
**<u>Wayne Ottinger:</u>** We think we had about the right amount in flight test out at Edwards on the RV, we undershot at Ellington, then we overshot on the reaction …, if you do it right you come with a fairly modest CRM support for any LLTV…
**<u>Brent Cobleigh:</u>** Add in the hazardous chemicals for the RCS, you've got an operational red there too.
**<u>Charles Hobaugh (Scorch):</u>** I think there's ways around that, I think you're trying to make it fit the pattern you did before, but there may be a better way of doing now…I'm just saying, don't kid yourself when you think safety pilot's aren't [are] free.
**<u>John Kelly:</u>** Shooting to minimize the amount of people necessary is I think is definitely a desirable goal

PDF/DVD version: Video Clip: Click to run, Right click to select floating window or full screen play controls at bottom:

**CWO Comment:** Significant improvements in both CRM and hydrogen peroxide handling for the rocket system with improved materials will offset the concerns and enable safe operations of a new gimbaled jet.
**[38] DRS Comment:** "….try to divorce yourself from…" – NO. See [36] above.

# Appendix A

## Commentary From Dr. David R. Scott, Apollo 15 Commander

September 2, 2009

To: Wayne Ottinger
From: DRS
**Subject: NOTES to accompany "DRS comments on the LLTV JSC Transcript"**

The following Notes as identified by letter provide further explanation and discussion regarding DRS Comments on the LLTV JSC Transcript, Dec, 2009. For each Note, the Transcript topic (subject matter discussed) and [#] numbered DRS comments (in blue) are shown for reference.

These Notes as well as the corresponding comments are provided in the context of a near-term (years) human lunar landing program, and in particular the Constellation program. Should such a program become a longer-term endeavor (decades), then many of these comments may not be relevant. An example is discussed in "Note C" below, Automation & Robotics.

## Note A. 2nd stage effect

**neil new lltv safer** (1 min 33 sec) (In Point at 1 hour 13 min 23 sec of NASA Tape 2)

[1] -- DRS comment: However, one must avoid the 2nd stage effect (see Note A)

The explanation of the term "second stage (system) effect" was brought to my attention in 2004 during discussions with the editors of the *Apollo Flight Journal,* primarily Frank O'Brien, who has a degree in computer science where the term was apparently first used in teaching. Frank's memo on the subject is summarized as follows:

> *"The Second System is one that, after an architect creates a wonderful, elegant *something* (software/building/spacecraft/whatever), the *next* attempt is likely to be bloated with all the things that never made it into the first, more elegant iteration. The first time through, you are limited by resources and what you don't know, resulting is a design that is very focused on conservative, well defined requirements. "Mission creep" is less of a problem with First Systems, if only because the only "mission" is to get things working the first time."*

You will note that this applies to any "system," not only computers. More can be found at the *Apollo Flight Journal* web site (http://history.nasa.gov/afj/), Another term for this is "Brooks Law" as is explained in http://www.answers.com/topic/brooks-law, which also provides many links for more detailed discussions.

## Note B. Mars capability

[1]... and the emerging tendency to include: (a) Mars landing capability (Note B);

Mars is a very, very difficult program, and very long-term in its planning, preparation and funding (which is of course no surprise). However, the "technology" to be used will be very different from the technology of today; e.g., as you might expect, the software programs of today will be stored somewhere in a dark corner of a forgotten warehouse (at best) – doubtful that this will be re-vitalized; the people who are fortunate enough to be assigned the Mars program will have their own technology

The Constellation program required Mars capability to be designed into the lunar capability. Attempting to combine lunar and Mars requirements in the design, development, and operations of a lander will compromise both, just as such expansion of capabilities has so many times in aircraft programs. Three things will happen to the lunar program if Mars capabilities are required in the lunar mission "architecture" (whenever it is formulated), the lunar program will experience: (1) increased cost; (2) increased schedule; and (3) increased risk. Let the Mars folks design and develop their machine when the time comes.

**Note C. Automation & Robotics**

[1] … and (b) automation and robotics (Note C).

Automatic (robotic, AI) capabilities are becoming quite advanced, they are challenging and they are fun to develop. But they are not necessary, or even desirable for a "manned" lunar landing -- they will introduce complex and additional failure modes during the mission as well as require the corresponding time and resources necessary for integration; test and checkout; software verification; procedures development (normal, malfunction, and emergency): C&W logic and signals; mission techniques; mission rules; simulation (such as launch abort sims due to time criticality); training; and real-time mission support,…among other factors (e.g., the age-old problem – if a red warning light flashes, what is at fault: the system or the indicator? And during the time-critical landing phase, the delay in assistance from MCC could cost the farm).

Automatic (robotic, AI) systems are best applied to two areas: (1) to relieve the human burden of repetitious, tedious, and boring activities; and (2) to allow humans to do something that could not be done without assistance from an "automatic" system (e.g., a precision landing on a runway during zero visibility conditions). Landing on the Moon is an entirely different matter –the surface of the Moon is irregular in all aspects and even with precision (e.g. virtual reality) planning and programming, it is unlikely that an automatic system will be able to "see" (interpret) the surface conditions as well as the eye. Automatic (robotic, AI) systems would be great for an unmanned landing, but they are unnecessary and even compromising for a human landing.

Airliners are excellent at automatic landings, and the ground-airborne systems are superb. Pilots are able to land an airliner in zero visibility -- that is, on Earth an automatic landing will be successful even when the human cannot see the target point. However, on the Moon, with current technology, the system cannot direct the vehicle to a suitable landing point; only the eyes and skills of a pilot can direct the lander to a suitable landing point. However, in the future, especially with better knowledge of the landing point (higher resolution photos, better gravity models, etc.), an automatic landing could very well be as effective as an Earth auto land – but this advanced capability will obviously require time and money.

**Note D. Need for an LLTV**

**gene risk here not on the moon** (0 min 42 sec) (In Point at 1 hour 15 min 09 sec of NASA Tape 1, Disc 2)

[2] -- DRS comment; The LLTV risk environment on Earth is far less than the lunar lander (LM) risk environment at the Moon. In the Earth environment, the situation is under better control, and it is shorter term with a simpler vehicle. And at the Moon, both the mission and the crew are at risk – a risk that can be reduced by having a qualified and proficient pilot at the controls. Only an LLTV-type vehicle that very closely replicates the LM can provide the qualification and capability necessary for a successful lunar landing (Note D).

The experience. Landing on the Moon is a brief, and very unforgiving, experience. Many factors are involved – each and every factor must be considered and evaluated continuously. These factors include vehicle dynamics and motion, control and handling qualities (including response time), landing point selection, time available, control systems operation, computer operation, and the operations of all of the other many vehicle systems. Therefore, it is essential that as many of these factors be integrated into the pilot's training and proficiency as possible.

What's the task of a free-flying Lunar Lander Training Vehicle? (A) To place the pilot in the control loop as an active (direct) and feedback element. (B) To condition (train) the pilot in the highly dynamic and short time-constant flight operations. (C) To enable the pilot to readily and comfortably enter an effective performance "zone" during landing operations (see Note J).

Pilot qualification and proficiency. Not only must the pilot demonstrate qualification in the LLTV, but the pilot must also demonstrate a high degree of proficiency in the LLTV. Otherwise, the pilot will not be suitable for a lunar landing (see also Note L.) As the old adage reminds us:

> Aviation itself is not inherently dangerous.
> But like the sea, it is terribly unforgiving
> of any carelessness, incapacity, or neglect.

And the STA, albeit a very good trainer should not be used for analysis or comparison – the capabilities, objectives, and training benefits of the STA and the LLTV are entirely different. As examples, Shuttle approach and landing can be simulated in various aircraft (systems and procedures in other simulators); whereas the LLTV training for lunar approach and landing is absolutely unique (no other trainer, including Langley, could be used for this objective). See Note P.

## Note E. LLTV Handling and Control

**Gene do all you can** (1 min 15 sec) (In Point at 1 hour 05 min 23 sec of NASA Tape 2)

[3] -- DRS comment: Agree. The LLTV configuration and controllability (handing qualities) are absolutely unique and tailored to replicate the same on the LM (Note E). It is unlikely any other flight vehicle, modified or not (currently known to the industry) can perform the same function.

The motion of a lunar lander is absolutely unique. In particular, the 3-axis horizontal and vertical velocities are strongly and instantly coupled as functions of engine thrust level and vehicle attitude (R, P, and Y). that is, the 3-axis translation depends on the relative vectors, which can be controlled by the throttle as well as the attitude (pointing) of the vehicle. Therefore, only a free-flight LLTV-type vehicle can be used for realistic and efficient simulation. These multi-variable operations cannot be adequately simulated in a fixed-base or moving-base simulator. Further, the LLTV-type free-flight motion cannot be simulated by a helicopter or hovercraft (either of which can however simulate the flight along the landing trajectory and/or directional path).

"Aircraft" do not have the dynamic response or handling qualities of a lunar lander, and they are also subject to aerodynamic forces that would be difficult to filter or cancel – thus they are not practical for lunar landing simulations. However, helicopters are quite useful in becoming familiar with steep descents and are a valuable precursor to an LLTV type vehicle.

## Note F. Flight Vehicle Experience

**john young no lltv, crashes** (0 min 13 sec) (In Point at 09 min 48 sec of NASA Tape 1, Disc 2)

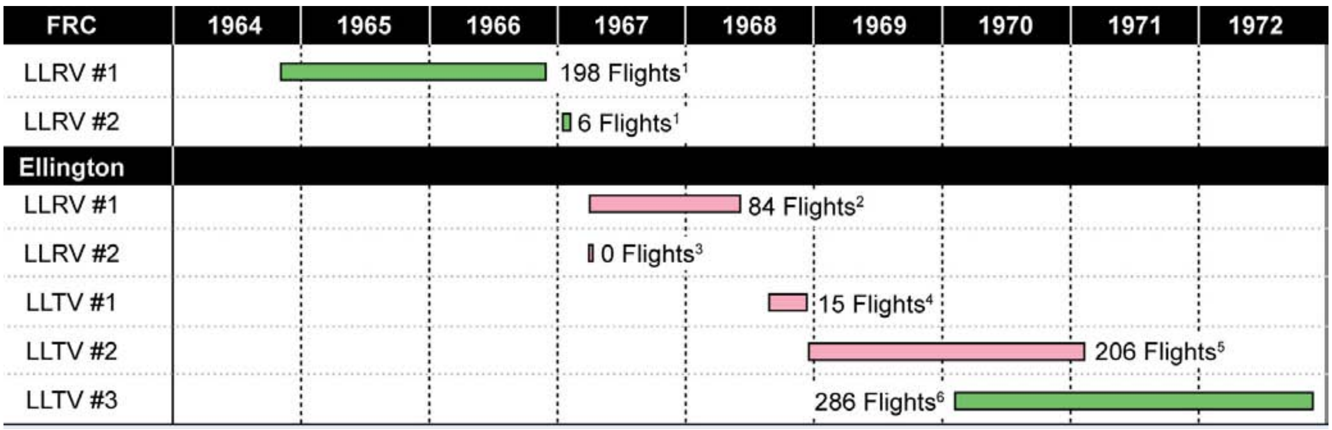
[4] -- DRS comment. The actual LLTV flight record must be analyzed before such a comment is made. As an analogy, not unlike fighter squadrons in the 50's, upon the introduction of a new flying machine, problems occur, often serious problems. Thereafter, based on experience and maturity of the flight vehicle, the pilots, and maintenance, the problems diminish significantly (Note F). …

Historically, upon introduction, new flying machines go through a transition period of learning and experience which is often characterized by "accidents." In recent times, one of the most advanced flight vehicles ever designed, the F-22, has unfortunately experienced three accidents. One would now expect significantly improved F-22 operations in the future.

During earlier times, and as an illustration based on my personal experience, some years ago I joined a fighter squadron that had an exceptional safety record, with highly experienced pilots, ground crews, and maintenance – over four years of F-86 operations, some 40,000 hours without an accident. We then transitioned into the F-100 – during the next 14 months this same squadron experienced 8 accidents (major and minor); thereafter the operations smoothed out with only 3 accidents during the next 4 years (2 due to ground radar flight control) – a maturity record not unlike the LLTV.

**Note G**. LLTV Experience

[4] …..The LLTV is typical – after 4 years of introduction with 3 losses, during the following about 3 years (1 year overlap), LLTV #3 flew 286 flights without loss, through the end of the program (Note G). Thus the comment that "we crashed three out of four" is not a proper assessment, especially for a program that matured and concluded at a high point of success.




**Note H. Failure Detection**

**schmitt manual ldgs** (0 min 21 sec) (In Point at 0 hour 58 min 10 sec of NASA Tape 1, Disc 2)

[8] -- DRS comment. "Manual" landing actually means "pilot-in-the-loop." We called these manual landings because the pilot was controlling the vehicle manually (by hand) – but in actuality, the hand-controller inputs were going through the computer, which itself could have landed the LM automatically (albeit never used). Being in the loop provides more than just a good feeling (which it definitely does) – being physically in the control loop has several operational benefits: (a) the pilot is tuned, or on top of the situation, -- if a failure occurs during an auto land, the pilot must recognize (accept) the failure and instantly insert himself into the control loop; which requires a finite amount of time; and (b) being in the loop at the time of a failure removes the ambiguity of determining whether or not an indication of a failure is actually a failure of the system or a failure of the indicator (see Note H).

> "On Tuesday afternoon, after NASA fueled the shuttle's huge external tank, one instrument showed that the fueling valve failed to close, while other indicators told launch controllers that the valve closed fine. With that uncertainty, the launch team scrubbed Wednesday morning's launch attempt and decided to try for shortly after midnight Friday. Now NASA is looking at 23 hours and 37 minutes after that, 11:59 p.m. Friday" ("NASA scrubs tonight's launch; next opportunity is Friday night." *Orlando Sentinel*, August 27, 2009).

Imagine attempting to troubleshoot something like that during the final 2 minutes of a lunar descent and landing…!!

**Note I. Vehicle Motion**

**I knew it was – been in the tv** (0 min 10 sec) (In Point at 1 hour 01min 08 sec of NASA Tape 1, Disc 2)

[13] - DRS comment. Another factor is the motion that the pilot feels, especially while maneuvering briskly – and correspondingly a motion that the LMP is not familiar with. That is, unexpected physical motions and forces are distracting, and the pilot in particular must be inherently tuned to this motion (see Note I).

To illustrate this point, it is useful to review the onboard transcript and comments from Pete Conrad and Alan Bean as recorded in the Apollo Lunar Surface Journal.

*__110:31:06__ Bean: Oh! Look at that crater; right where it's supposed to be! Hey; you're beautiful. Ten percent (fuel remaining). 257 feet, coming down at 5; 240 coming down at 5. Hey, you're really maneuvering around.*

*__110:34:08__ Carr: Roger, Pete.*

*[I asked Pete about the value of this training.]*

*[Conrad - "I think everybody agreed that the LLTV was very essential to a successful landing. One of the problems which we were talking about earlier at lunch is that you have to realize that the visual on the simulator was very bad. We had a plaster-of-paris lunar surface (called the L&A) and a B&W television camera that (flew to it). So you're looking at a flat, no-depth boob tube - a television - in the window. So, the last five hundred feet, if you were watching that out the window in the simulator, it wasn't any good. It just didn't really resemble the real world."]*

*[Conrad - "It was the best they had at the time. We didn't have a moving-base simulator, either. (In more recent times, Shuttle crews have been able to train in simulators that move in response to crew inputs and, thereby, give much more realistic simulations.) So, the LLTV was critical, to get a real feel. And the reason Al made the comment about maneuvering is that the LMP's didn't fly the LLTV."]*

*[Conrad - "Al hadn't flown one, and that's why he made the remark when I started really maneuvering the thing around. Because you had big attitude changes up there, because you're in a low gravity field. He had seen that kind of a maneuver, probably, inside the simulator. But that virtual image display and the fixed base didn't really give you any feel for it. So, the first time Al really experienced that was at the Moon. And I just passed it off 'Yeah, I'm busy doing what I was doing.'!"]*

*[Bean - "We were all flying helicopters and you didn't maneuver a helicopter any where near like that. Up there, you really had to move the LM to maneuver it. So Pete got used to it and I was thinking helicopter kind of stuff. So, when you (Pete) suddenly maneuvered much more than a helicopter, it caught me by surprise. But to you, well, that's the way you do it. I think it's because, on Earth, you're supporting the weight with a certain amount of thrust. So, let's say you've got to knock off ten foot per second forward. You pitch up to a certain angle to do that and you get used to that kind of maneuver. You go on to the Moon; you've got one sixth the thrust to hold this same mass up and ten feet per second forward with that mass is the same as it was on Earth. But, in order to stop it (from moving forward) with one-sixth the thrust, you're going to have to pitch up a lot harder. So I think it's just strictly the fact that you're operating with less thrust than a helicopter for the same weight and the same momentum. So, in order to use it, you've got to get that thrust vector up higher faster or you're just never going to slow down the translations, or get one going and then stop it. When you think about it, it makes sense. But, at the time, it just seemed like 'God, what's he doing?' It felt to me like you were pitched too far (back), you know. And you probably were doing quite a bit because you've got to get it (pitched) up there to get the little ol' thrust vector to work."]*

*[Conrad - "That's right, you have to move it more to get the maneuver. So it looks really bad to you, although nothing serious is happening."]*

*[Bean - "It looked normal to you!"]*

This shows that without LLTV training, the pilot will be surprised by the motion during actual landing, and of course distracted as well as questioning whether or not the LM is behaving properly an/or whether or not there is a failure in the control system.

This also introduces in the case for fixed-base vs. motion-based simulators. Motion in space is benign (except tumbles); motion during landing is dynamic and time of flight is extremely limited. An LLTV is essential for the dynamic elements of a landing simulation – a fixed-base simulator is fine for procedures development and systems training. Therefore, the combination of an LLTV and corresponding fixed-base simulators is optimum; both from training and cost perspectives. Learn to fly the LLTV and learn procedures and systems in a fixed-base simulator (no need for a motion base).

**__Note J. Zoning__**

**gene neil training reactions same** (0 min 36 sec) (In Point at 1 hour 33 min 00 sec of NASA Tape 2)

[14] - DRS comment. This could be considered part of the "zoning" process (Note J) – we all learned to completely focus on the intense and demanding task of landing a vehicle on the moon. We were all trained into essentially the same performance box. As an analogy, we all (most of us) land airplanes in approximately the same manner.

"*Zoning" (also known as "Flow") can be explained as "the mental state of operation in which the person is fully immersed in what he or she is doing, characterized by a feeling of energized focus, full involvement, and success in the process of the activity*." Initially proposed by psychologist Mihály Csíkszentmihályi, the concept has been widely referenced across a variety of fields. Colloquial terms for this or similar mental states include: *on the ball*, *in the zone*, or *in the groove" (*http://en.wikipedia.org/wiki/Flow).

This was not a familiar term during Apollo, but this is what we did – during descent and landing; and because of LLTV experience, we actually entered what is now known as "The Zone"-- for lunar landing. The term is now widely used in sports psychology and clearly defines our "psychology" in both training and actual operations. To better understand the zoning concept as it relates to the LLTV and a lunar landing mission, review one of several published explanations of zoning; e.g.., "Entering 'The Zone': A Guide for Coaches" (http://www.thesportjournal.org/VOL2NO3/COSTAS.HTM). Also see on the internet: "Using Sports Psychology to Achieve a Zone Focus."

As a final comment on this, see the lengthy discussion of the Apollo 15 Landing at 102:42:48 in the *Apollo Lunar Surface Journal* (http://www.hq.nasa.gov/alsj/frame.html), part of an interview with Eric Jones during 1992-1993 -- note that even then, I felt that I was on "automatic."

> *"The LLTV landings were manual landings, and the LLTV was a great trainer. I mean, boy, am I glad we had that, because it gave me confidence that I knew what I was doing on the Moon, and I didn't have to think about things. I didn't have to consciously program myself to do things. I was automatic. So, my feeling was, if you can land the LLTV, you can land a LM."*

## Note K. 2nd (Safety) Pilot

**Reset Button & Altair Gimbal RV Sim** (5 min 17 sec) (In Point at 1 hour 40 min 15 sec of NASA Tape 2)

[25] - DRS comment. The LLTV does put you on the line and it forces you the think the lunar landing profile (Note J) – it does not have a reset button such as a simulator, but it does have a breakout capability to exit the lunar sim and then land in a much easier and safer mode. A safety pilot actually increases risk (see Note K).

I strongly favor the solo LLTV configuration (pilot only) for the following reasons, among others:

1. What would the 2nd (or "safety") pilot do?

   - Call out corrections? (and interrupt the pilot – the Flight Director can communicate systems problems).
   - Make comments during an intense maneuver? (and slow the pilot's thought process – the pilot should not be distracted by 2nd pilot opinions)
   - Act as the LMP? (The LMP gets his training in the LMS; and the PILOT must be able to land without LMP communications anyway)
   - Grab the controls if he does not like the situation?
   - Get a thrill; be frightened.

2. What controls and displays would be added for the 2nd seat? What overrides? All of which would need to be integrated into the total system and result in additional failure modes, more complex mission rules, and more complex flight operations.

3. Adding a 2nd place will increase cost, schedule, and most importantly risk – for no recognizable return (that is, it is unlikely the 2nd seat would add anything meaningful to the training, and indeed subtract from it).
4. No time to do anything that would contribute to safety (but could detract from safety).
5. Distracting to the pilot.
6. Might provide reliance by the pilot in certain situations where the pilot should make the decisions rather than rely on a safety pilot – thus perhaps providing a false sense of security
7. Communications might conflict with and confuse the comments from the Flight Director (who would have much more data)
8. Pilot decisions must be based on the task at hand; and not based on having a passenger for which the pilot is ultimately responsible.
9. How many of the 2nd seat people would have survived the three losses of the LLTV during Apollo?
10. Certainly not going to give the 2nd seat the trigger to eject.

Remember that the LLTV pilots are not (should not be) beginners; they should already be comfortable in solo checkouts of new and/or high performance flight vehicles (e.g., grads of a recognized TPS).

## Note L. Management Responsibility

**scorch $ should not drive** (0 min 28 sec) (In Point at 1 hour 13 min 24 sec of NASA Tape 1.Disc 2)

[27] - DRS comment. But money is a reality and must be a factor in management's analysis. However, management's responsibility in committing the crew to a landing must also be weighed in the tradeoffs of LLTV cost and risk (Note L – very important).

The responsibility of senior management is to ensure the highest probability of success of the mission coupled with minimum risk of loss. The LLTV-type vehicle (LLTV) itself contributes to both. But the pilot of the Lunar Lander (LM, Altair, etc.) must be proficient in the LLTV; that is he/she must have demonstrated – repeatedly -- very high-quality flying capabilities and flight-management skills. To send somebody to land on the Moon (planet, etc.) who has not proven him/her-self in an LLTV-type vehicle would be irresponsible – that is, without demonstrated capability in the LLTV, a non-qualified pilot would lower the probably of success and increase the overall risk of the mission.

To quote Pete Conrad: "*We are banking our whole program on a fellow not making a mistake on his first landing." Digital Apollo*, David A. Mindell, MIT Press 2008 (p 181).

## Note M. Time Compression

**Neil 11 gene psycho** (4 min 30 secs) (In Point at 0 hour 44 min 07 sec of NASA Tape 1, Disc 2)

[28] - DRS comment. The fuel limits were a very valuable contribution to the overall preparation for the LM landing. This limit forced early decisions on the approach and touchdown, which if anticipated gave us time to change the touchdown point during the final gallons of fuel – something to learn based on the actual Apollo 11 experience. This additional limit also helped compensate for time-compression during the actual mission (Note M).

As quoted from Ken Szalai (2-21-2008) in the Go For Lunar Landing Conference charts, March 4th and 5th, 2008: *"The lifting body pilots were unanimous in reporting that, once in flight, the events of the mission always seemed to progress more rapidly than they had in the simulator. As a result, engineers and pilots experimented with speeding up the simulation's integration rates, or making the apparent time progress faster. They found that the events in actual flight seemed to occur at about the same rate as they had in the simulator once that simulation time was adjusted so that 40 simulator seconds was equal to about 60 "real" seconds."*

This ratio of about 7 to 1 was just about the same as I believe most of us experienced during Apollo; that is, it seems that the time available in flight is about 70 % of the time used during simulations. One of the common phrases was "get ahead, and stay ahead." NASA never implemented this simulation philosophy, and I don't know why. But the LLTV certainly taught us this valuable lesson.

During Apollo 15, I went to manual at about 400 feet, and landed 81 seconds later (55 seconds sooner than the propellant budget provided). Observing the DFRC experience in time compression during a flight, whereby 60 actual seconds seems like only 40 seconds of available time for operations, my 81 actual seconds probably seemed like 54 seconds (it certainly went quickly). A typical LLTV profile from 400 feet to touchdown takes about 69 seconds – great training for the 54 flight seconds that I experienced. Thus, the available time, and time usage, during my lunar landing felt very similar to my experiences in the LLTV.

And this was a most important lesson, because (to again quote from Ken Szalai*); "…the consequences of fuel exhaustion were nearly the same for the LLTV mission as for the LM landing*." But of course there was much more on the line during the lunar landing; even more reason to be well schooled in this art.

**Note N. Negative Training**

Several items have been identified as negative training in this discussion; among these the following should be emphasized.

Note N-1. Propellant

**Neil 11 gene psycho** (4 min 30 secs) (In Point at 0 hour 44 min 07 sec of NASA Tape 1, Disc 2)

[28] … Further, having more fuel (time) than actually available during the lunar landing would be negative training, it would preclude the pilot from integrating the time factor into his thinking (Note N).

Time to landing is a direct function of propellant remaining. The LLTV flight profile approximates very closely the time remaining for the lunar lander during a near-identical flight profile. The time remaining during descent (or propellant available) must be integrated into the pilot's flight profile and decision-making. Therefore, providing an excess amount of propellant during an LLTV flight would provide negative training in that the pilot might become complacent regarding the amount of time remaining before a commitment must be made to land or abort (regardless of warning lights or any other indications).

Note N-2. Systems

**Complexity of off-nom tng vs skill tng** (3 min 39 secs) (In Point at 1 hour 07 min 14 sec of NASA Tape 1, Disk 2)

[30] - DRS comment. The purpose of the LLTV is to teach the pilot how to fly, not how to analyze systems that are different from those of the LM – for the LLTV, that's the job of the LLTV flight control team (CRM) (and for the LM, that's the job of the LMP and MCC ). Therefore, absolutely no need or purpose to insert intentional systems failures or simulated failures in the LLTV for training; those would be another aspect of negative training (Note N).

The inclusion of LLTV systems failures during an LLTV flight, would result in the following negative factors (among others).

1. Need for pilot to become proficient in systems additional to and different from the LM (and CSM) – requires more training, documentation, and coordination with the CRM.
2. Distracting from the primary purpose of the LLTV – to teach the pilot how to fly.
3. Increases time, effort and complexity of pilot training.
4. Increases overall cost, schedule and risk of the LLTV.
5. Different systems in a similar vehicle (LLTV) could become a confusion factor in the pilot's operations of the actual LM.

**Note O. CDR Window Display**

**neil rate of descent cmd** (1 min 37 sec) (In Point at 1 hour 01 min 56 sec of NASA Tape 1, Disc 2)

[35] - DRS comment. The ROD was great; but still, becoming proficient in the LLTV "manual" landing is most important – for both the potential failure of the ROD as well as to appreciate the ROD function. Another recommendation to reduce the pilot's load in the cockpit is to add a pipper to the LPD grid; that is, a "dot" on the CDR's window that moves along the grid according to the two-digit numerical computer projections of the landing point. This would correspond to (or substitute for) the DSKY numbers being read by the LMP. Any other CDR window display would be superfluous and detract from the visual and mental requirement of selecting and flying to a specific touchdown point (Note O).

The verbal transfer of information was not cumbersome and in fact optimized the landing technique – that is, "we" landed on the Moon – the machine (LM), the CDR (eyes outside), the LMP (eyes inside), and MCC (many eyes). Therefore, the LPD as a representative HUD would be fine. Otherwise, don't block the CDR's view or distract him with information that can be provided through his ears by the LMP and MCC.

As an example, on A-15, we found that the optimum technique was for the CDR to focus out the window and the LMP to focus inside the cockpit. The CDR maximized the landing point information through his eyes while absorbing the LM gages and systems through his ears (LMP and MCC); thus optimizing all sensors available. The verbal transfer of information from the LMP to the CDR was a most effective technique to optimize the use of all of the information available – that is, with proper training and coordination, each of the LMP and CDR could focus on assigned tasks without dilution, confusion, or subtracting from the maximum use of available information.

The lunar landing as we implemented it on A-15 was not unlike landing in formation during bad weather – one pilot has his eyes in the cockpit scanning all of the information available and the other has his eyes outside searching for the runway – when the outside eyes see the runway, "contact" is called and the lead comes out of the cockpit and begins the flare to touchdown. Prior to that, the lead is completely inside the cockpit "on the gages." Both hear ground control, e.g., GCA, and the lead reacts to the information provided.

A HUD on the LM that duplicates most of the data being read to the commander (CDR) would require the CDR to scan, refocus and interpret the display. Also, situational awareness, especially when landing on the lunar surface, includes "terrain awareness" as well. With the field of view cluttered up with pretty but marginally useful graphics, some of that awareness would be lost. Further, any failure in the display itself would be another undesirable distraction.

However, adding a pipper to the LPD grid would be helpful -- that is, superimposing a "dot" on the LPD grid that moves along the grid according to the two-digit numerical computer projections of the landing point. This would correspond to (or substitute for) the DSKY numbers being read by the LMP.

In summary, adding an LPD pipper to the CDR's window would be fine. Otherwise, don't block the CDR's view or distract him with information that can be provided through his ears by the LMP and MCC.

## **Note P**. STA Comparison

**gene roger eye level** (1 min 10 sec) (In Point at 0 hour 0 min 0 sec of NASA Tape 2)

[20] - DRS comment See [17] above. However, regarding the STA comment, the physical configuration of the LLTV cockpit, especially controls and displays, should be exactly the same (or as close as possible) to that of the lunar lander. A blindfold cockpit check of all controls and displays is mandatory before proceeding to "checkout" in the lunar lander – standard aeroplane practice. Also, in general, caution on comparisons or analogies with other trainers, especially the STA (being a recent example of a unique trainer). See [23] below, and Note P.

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**gene Mash free flt lltv** (1 min 47 sec) (In Point at 1 hour 15 min 01 sec of NASA Tape 2)

[23] - DRS comment. The lunar landing is so unique, that an LLTV type vehicle is essential. Conversely, for the Shuttle approach and landing, if the STA were not available, training in an F-104 or similar low L/D aircraft would be adequate, the profile and judgment requirements are essentially identical, and control responses are similar. No known vehicle, other than the LLTV, can replicate the control responses of the lunar lander (LM) (Note P)>

The following comments are intended to illustrate the different characteristics of an STA and an LLTV as they relate to the design and operations philosophy of training a pilot for a landing. The comments have been drafted primarily for non-pilots, engineers or managers – most of the differences between the LLTV and an STA are probably obvious to those familiar with aircraft flight operations. However, these comments are also important for those skilled in aircraft (or helicopter) flight to understand the differences introduced by lunar-landing flight. In general, the STA and LLTV are obviously completely different flying machines with completely different flight profiles. Extrapolation from the SVA design and operations philosophy to the LLTV will most likely result in, among other problems, negative design considerations and negative training.

As background, I was very fortunate during my flying career to have had the opportunity to fly many "low L/D" approaches (and touchdowns). I was also fortunate to have had the opportunity to fly the LLTV. These are entirely different machines flying entirely different profiles. Many of the following comments may be obvious to those skilled in the art, but a review might be useful to assist a focus on the current situation. Also, the following comments are not meant to compare the STA and the LLTV directly since they fly in different regimes, it is meant to compare the design philosophy of simulating an aerodynamic vehicle that flies in a 1-G environment with simulating a different vehicle – under aerodynamic and 1-G conditions -- that flies in a 1/6 G vacuum environment.

1. **Flight profiles**

(a) **The low L/D approach** profile (STA, Shuttle, X-15, X-24, F-104, etc.) is an energy management technique based on proper positioning at a high gate, followed thereafter by careful attention to altitude, airspeed and approach angle. Only two degrees of freedom are required, roll and pitch; the vehicle then flies as a function of aerodynamic forces and gravity; propulsion is not involved.

(b) Conversely, **the LLTV approach** profile (manual) requires the same energy management skills, however, the profile is a function of roll, pitch, and engine thrust (throttle position) -- the vehicle then flies as a function of engine thrust and gravity. At the same time, the LLTV systems must in fact eliminate (compensate for) aerodynamic forces.

2. **Vehicle control**. The Shuttle (and STA) requires the pilot to use: (a) the rotational hand controller (RHC). The lunar lander (and LLTV) requires the pilot to use: (a) the RHC; (b) the throttle; and (c) the coupled combination of the RHC and the throttle. Therefore, the LLTV requires much more challenging pilot control and coordination, and correspondingly a more difficult training task.

3. **Response time.** The motion of a lunar lander is absolutely unique. In particular, the horizontal and vertical velocities are strongly coupled with -- and an instant function of – vehicle attitude; that is, the 3-axis translation depends on the relative vectors – these are controlled by the throttle as well as the attitude of the vehicle. The response time to "control" inputs is almost instantaneous -- not so with the STA, helicopter, hovercraft or ay other vehicle that relies on aerodynamic forces for motion, and that can be flown with relatively long time constants.

In comparison, things happen much more quickly in a lunar landing approach than in a low L/D approach – therefore, during an LLTV approach the pilot must anticipate necessary corrections much sooner than in a low L/D approach. In other words, and not to detract from the challenge of a low L/D landing, a low L/D landing is much less challenging than a lunar landing.

4. **Propellant.** Other than a fixed throttle setting, the STA requires no additional propellant to maintain its flight profile. The LLTV requires engine modulation, close monitoring and conservation of propellant, especially as the approach relates to selecting a desired touchdown point. Thus, the STA: no throttling required. The LLTV: the throttle, and the use of propellant, controls: (a) the remaining flight time, (b) the descent rate, and (c) the horizontal velocity (forward, aft, left, right).

5. **<u>Flight profile and time to touchdown</u>** – (considering the differences beginning at about 300 feet). The STA requires only a careful initiation of the flare and holding the pitch as the aircraft touches down. Conversely, this region is one of the most active periods of an LLTV flight in that roll, pitch, and throttle movements (coupled) may be quite rapid in order to find a suitable touchdown point.

6. **<u>Touchdown point</u>**. Most importantly, the STA makes its approach to a specific touchdown point on well-marked, smooth, level, specific-width surface (runway). The lunar lander makes its approach to a surface that not only has no specific orientation markings, but a surface that is distorted by craters, rocks, shadows, slopes, mounds, and other irregular features – and final touchdown is often IFR due to the dust. Yes, in training, the LLTV works to a runway, but the pilot has the opportunity to change the touchdown point at the last minute to simulate undesirable lunar surface conditions, whereas the STA touchdown point is fixed; that is, there is no reason for the STA pilot to change the planned touchdown point – however, as we have learned, the lunar lander pilot must often change the touchdown point at the last moment.

DRS

# Appendix B: Transcripts of the Introductory Videos of the Six Apollo Landings

Apollo 11

102:45:17 Aldrin: 40 feet, down 2 1/2. Picking up some dust.

Armstrong, from the 1969 Technical Debrief - "I first noticed that we were, in fact, disturbing the dust on the surface when we were something less than 100 feet; we were beginning to get a transparent sheet of moving dust that obscured visibility a little bit. As we got lower, the visibility continued to decrease. I don't think that the (visual) altitude determination was severely hurt by this blowing dust; but the thing that was confusing to me was that it was hard to pick out what your lateral and downrange velocities were, because you were seeing a lot of moving dust that you had to look through to pick up the stationary rocks and base your translational velocity decisions on that. I found that to be quite difficult. I spent more time trying to arrest translational velocity than I thought would be necessary."

102:45:21 Aldrin: 30 feet, 2 1/2 down. (Garbled) shadow.

102:45:25 Aldrin: 4 forward. 4 forward. Drifting to the right a little. 20 feet, down a half.

102:45:31 Duke: 30 seconds (until the 'Bingo' call).

102:45:32 Aldrin: Drifting forward just a little bit; that's good. (Garbled) (Pause)

Armstrong, from the 1969 Technical Debrief - ";As we got below 30 feet or so, I had selected the final touchdown area. For some reason I'm not sure of, we started to pick up left translational velocity and a backward velocity. That's the thing I certainly didn't want to do, because you don't like to be going backwards, unable to see where you're going. So I arrested this backward rate with some possibly spasmodic control motions, but I was unable to stop the left translational rate. As we approached the ground, I still had a left translational rate which made me reluctant to shut the engine off while I still had that rate. I was also reluctant to slow down my descent rate anymore than it was, or stop (the descent), because we were close to running out of fuel. We were hitting our abort limit."

Armstrong, from the 1991 ALSJ Interview - I guess that, at that altitude, running out of fuel wasn't a consideration. Because we would have let it just quit on us, probably, and let it fall on in."

102:45:40 Aldrin: Contact Light.

102:45:43 Armstrong (on-board recording): Shutdown

102:45:44 Aldrin: Okay. Engine Stop.

Armstrong, from the 1991 ALSJ Interview - "We actually had the engine running until touchdown. Not that that was intended, necessarily. It was a very gentle touchdown. It was hard to tell when we were on."

[Material edited out  for this presentation.]

102:45:57 Duke: We copy you down, Eagle.

102:45:58 Armstrong (on-board recording): Engine arm is off. (Pause) (transmitted) Houston, Tranquility Base here. The Eagle has landed.

Apollo 12

115:22:22 Conrad: I'm going to step off the pad.

115:22:24 Conrad:  Mark.  Off the...Oooh, is that soft and queasy.  (Pause, holding on to the ladder as he tests the footing)  Hey, that's neat.  (Pause)  I don't sink in too far. (Pause)  I'll try a little...(Letting go of the ladder and stepping out of the LM shadow) Boy, that Sun is bright.

[Material edited out for this presentation.]

115:23:27 Conrad: (Gleeful, as he looks east into the Sun)  Boy, you'll never believe it.  Guess what I see sitting on the side of the crater!

115:23:30 Bean: The old Surveyor, right?

115:23:31 Conrad: The old Surveyor.  Yes, sir.  (Laughing)  Does that look neat!  It can't be any further than 600 feet from here.  How about that?

Apollo 14

108:11:13 Mitchell:   Okay, there's pitchover.

Program 64 controls the "approach phase" of the landing and what happens first in P64 is that the LM pitches into a more upright position - from about 55 degrees off vertical to about 45 degrees, and then continues to pitch upright, but at a faster rate than was the case before P64.  The sudden change in spacecraft attitude at pitchover gives Shepard his first look at the landing site.

108:11:14 Shepard: (P)64 and we have pitchover, Houston.

108:11:15</b> Mitchell: There's PRO...

108:11:16 Haise: Roger, Al.

108:11:17 Shepard: There's Cone Crater.

Cone Crater was punched into a ridge, just above the center of the image after pitchover.

108:11:19</b> Mitchell: And there it is.

108:11:20 Shepard: Right on the money!

108:11:21 Mitchell: That's it.  Right on the money.

Shepard, from the 1971 Technical Debrief - "We came down to P64, pitchover, and there it was.  The landing area model was excellent in that
respect.  It was an excellent training tool, and there was no problem in recognizing immediately where we were."

108:11:22 Shepard: What's the LPD(Landing Point Designator angle), babe?

108:11:23 Mitchell: LPD, 41.

[Jump to EVA-3 at the point when Houston decides it is time to end the search for the rim of Cone Crater.  Photos from the traverse toward the ridge flank toward the rim]

133:23:17 Shepard: Well, I don't know what the rim is still way up here from the looks of things.

133:23:23 Haise: And, Ed and Al, we've already eaten in our 30-minute extension and we're past that now.  I think we'd better proceed with the sampling and continue with the EVA.

133:23:37 Mitchell: Okay, Fredo.

[In Houston, the Flight Director is told that tracking data indicates that the LM is headed for a point about 3000 feet south of the planned target. At first, the Flight Director decides not to tell the crew, knowing that Dave will see the difference at pitchover. However, Ed Mitchell immediately suggests that Dave be told. Mitchell flew as LMP on Apollo 14 and knows the value of having as much pertinent information as possible. The Flight Director approves Mitchell's request without hesitation.

104:39:17 Mitchell: Falcon, Houston. We expect you may be a little south of the site, maybe...

104:39:18 Irwin: Okay. Coming up on 8000 (feet altitude).

104:39:19 Mitchell:...3000 feet.

104:39:24 Scott: (Responding to Mitchell) Okay.

104:39:32 Irwin: 7000 feet. P64!

104:39:36 Scott: Okay.

104:39:37 Irwin: We have LPD.

LPD is the Landing Point Designator. In this mode, Dave can use his handcontroller to tell the computer to alter its target left or right, forward of back. From the computer readout, Jim will give Dave an angle which tells him where to look through scribe marks on the window to find the place where the computer thinks they will land. There are matching scribe marks both on the inner and outer panes of Dave's window and, if he positions himself so that those two sets line up, he will be looking at the proper point on the surface.

104:39:40 Scott: LPD. (Pause) Coming right.<p>

Now that the landing area is in sight, Dave is making the first of 18 redesignations of the landing site, correcting the approach path to the right moved the targeted landing site to the north.

104:39:45 Irwin: Four-zero (LPD angle)

104:39:47 Irwin: 5000 feet. (LPD angles) 39. 39. 38.

Apollo 16

Late in EVA-1, as planned, Charlie Duke gets off the Rover and takes the 16-mm movie camera to film John Young driving the Rover. This is called the Grand Prix and is being done at the request of the Rover engineers. John drove away from Charlie toward the LM. This clip starts after John turns and drives back toward Charlie.

124:57:30 Duke: And the DAC is running. Man, I'll tell you, Indy (meaning the Indianapolis 500)'s never seen a driver like this. (Pause) Okay, when he hits the craters and starts bouncing is when he gets his rooster tail. He makes sharp turns. Hey, that was a good stop. Those wheels just locked.

124:58:03 Duke: Mark, (the camera's) off.

Apollo 17

112:59:01 Schmitt: Okay, stand by for pitchover.

112:59:04 Cernan: Oh, are we coming in. Oh, baby.

112:59:11 Schmitt: Okay; through 9000.

112:59:12 Cernan: Stand by for pitchover, Jack.

112:59:14 Schmitt: 8000.

112:59:15 Cernan: I'll need the Pro(ceed).

112:59:16 Schmitt: I'll give it to you.

Schmitt, from a 1993 ALSJ Interview - "By hitting the Proceed button, the computer would start the next program in its repertoire. There was a whole series of programs called P64 and the like, this one being the program for events after pitchover."]<p>

Cernan, from a 1993 ALSJ Interview - "Pitchover was very critical. I needed to look out the window to make sure the LM didn't pitch over too far; so this was one of the few instances in which we had planned for Jack to enter a command into the computer so that I didn't have to look down. Learning how to work together during the landing sequence was a critical part of our training. You get procedures, you get checklists, but two guys still have to learn how to work together and coordinate their resources effectively. This is a good example of that, and one that was much more critical than the lunar surface work."

112:59:18 Cernan: Pitchover.

112:59:19 Schmitt: There it is!  Proceeded.

Cernan, from a 1993 ALSJ Interview - "We still wanted to slow ourselves down by firing forward but now we also had to keep ourselves from falling in too fast toward the surface.  I don't know how much we pitched over, maybe from about sixty degrees to about twenty or thirty degrees (actually from 60 degrees to 20); but, when we did, all of a sudden, bam, the lunar surface filled up almost the entire window."

112:59:21 Cernan: And there it is, Houston.  There's Camelot (Crater)!  Wow!  Right on target.

112:59:24 Schmitt: Wow!  I see it.<p>

112:59:25 Cernan: We got them all.

Cernan, from a 1993 ALSJ Interview - "Although there is nothing quite like the real thing, flying the Lunar Landing Training Vehicle had been a step  toward realism from 'flying' the stationary simulators.  In the  LLTV you had your butt strapped to a machine that you had to land safely or  you didn't make it.  It still wasn't landing on the lunar surface, but it  gave you a feel for what the actual landing would be like.  Similarly, in  simulator training we'd had a TV picture of a (large) model of the landing site that  was good enough that, when we pitched over during the actual landing, I felt like I'd seen the landing site before.  I won't say that I totally felt like I'd been there before, but I felt like I'd seen that valley before, three  dimensionally.  So it was a very comfortable feeling to know we were right  where we expected to be."

112:59:26 Schmitt: 42 degrees, 37 degrees through 5500.  38 degrees...

112:59:32 Fullerton: Challenger, you're Go for landing.

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## LLRV Test Pilot Don Mallick Inputs

**Questions for LLTV/LLRV and LM Pilots from DFRC 9/17/08**

1. What's the task of a free-flying Lunar Lander Training Vehicle?

a. Should it simulate the approach phase or just the landing phase?

b. Based on your experience, can you put into perspective the difficulty of the landing task and comment on how pilot work load varied over the trajectory?

2. For a lunar landing training vehicle, how essential is roll and yaw in the simulation?

a. Since there is no atmosphere for the final landing phase wouldn't we be using mostly translational controls?

b. During you training or actual lunar landing did you use much roll or yaw control during the final landing phase? How about pitch?

Note: We are looking at helicopters, V-22, AV-8s, gimbaled jets, etc. each of them has there own pluses and minuses. Some options sacrifice some of the simulation, some are more costly than others, and some have a safety stigma associated with them (i.e. gimbaled jet, AV-8)

3. Do you think with modern advances over the last 40+ years in digital flight controls, engines, etc. we could make a gimbaled jet (like the old LLRV/LLTV) that could safely do the mission?

4. Having flown the lunar lander and the LLRV/LLTV how would you build a modern free flight trainer or would you?

5. What somatosensory cues were important with respect to landing on the moon? How well did the LLTV replicate these cues?

a. As a corollary, what did the landing task "feel" like? For example, what were the perceived pitch sensations, accelerations, etc. (physiological sensations)
b. To what fidelity should we strive to replicate the physiological sensations of the Lander? How important is physiological relationship training to mission success?

**Don Mallick's Answers 9/18/08:**

Hi Wayne:

I am answering the questions on the new training vehicle, as I see it from my experience with the LLRV, and observing the operation of it by Houston. I will identify the question, by number, just giving my answer here:

1. a. It should include the final approach phase, along with the landing phase. Also, some lateral translation tasks should be included that require the pilot to maneuver from the initial hover to the final touchdown area.

1. b. Maneuvering the vehicle to the starting or entry position of the approach was a light to moderate work load. This included setting precise altitude, velocity, and location to initiate the lunar simulation.

Once established in the descent and approach, the work load was medium and involved flying visual, with some instrument referral and making corrections in attitude (to adjust position relative to the hover point) and altitude rate.

The final flare to a hover required an increased concentration and workload to bring the vehicle to a hover over a spot and at the proper altitude. If a planned "offset" was used as an increased task, the translation and movement to the desired location, again required an increased work load.

Final landing and touchdown, the workload continued high, holding a steady hover and precise altitude rate until touchdown and completion.

2. To fly a vehicle in the 4 dimensional environment, the pilot needs four dimensions of control. Pitch, Roll, Yaw and altitude rate control.

a. The controls are required to handle any moment, such as thrust misalignment, coupling or even small cross winds that can be present, flying in the earth environment.

b. Control inputs were required in all three axis during the actual landing. Pitch and roll were used to create any lateral translations required, and yaw was utilized to maintain the desired heading at touchdown. Of course, altitude rate to make a smooth touchdown.

3. YES

4. I would start with the proposed Lunar Landing Vehicle. The astronauts location and view of the lunar landscape during the approach and landing would be important in the seating configuration of the LLRV. Although the astronauts were standing in the LEM, they had a visual picture not too unlike the LLRV.

On the vehicle itself, my feeling is, Why re-invent the wheel. Improve the machine with lessons learned. VERY IMPORTANT--The training should be at the same location as the flight development and proof on the vehicle occurs. Same atmosphere, same weather, same winds, same problems, same people involved, that did the development. I personally feel this was one of the biggest problems with the LLTVs and the ones we lost.

5. Sorry to say, this one is a DNA for me.

Donald L. Mallick
LLRV Pilot

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Donald L. Mallick
LLRV Pilot

## **Email from Don Mallick 10/14/08:**

Hi Wayne:

Good talking with you this morning (10-14-08) and getting updated. You raised the question of an IP or safety pilot position in the "future" LLTV. I repeat my response and thoughts to you on that.

If the actual Lunar Landing Vehicle is going to have two sets of flight controls and pilots, then it would be appropriate to have that on the LLTV. However, if that is not the case, I would not favor an IP or instructor's station on the LLTV. I know that sounds "counter" to all ideas of safety, and that IP's and safety pilots have been used for years in flight training. However, I think in the interest of the best simulation that you can provide the Astronauts, I feel the control situation should be as close to the main Lunar Landing Vehicle as possible. I recall reading Astronaut comments to that very point. The LLTVs were excellent simulators that did have a degree of risk, but gave them a solid preparation.

I recall the difference in personal attitude between flying the Langley Lunar Landing Trainer and the LLRV. There was no I.C. Stop on the LLRV and the realism and fact you were flying the machine in space, with all the possibilities, made it a excellent trainer.

I might add, if there is a systems man that backs up the astronaut on the actual Lunar Landing, it would be appropriate to have the same function on the LLTV. However, if that is not practical, the ground monitoring personnel could provide that, as they did on the LLRV's at Dryden. I always had the feeling that there was a systems man backing me up, almost looking over my shoulder and alerting me to any item in question. Of course, he was in the ground control station, monitoring from there.

Don Mallick
LLRV Pilot, NASA Dryden

Used by permission from Eric M. Jones

# Utility of the Lunar Landing Training Vehicle


**Last revised 30 September 2008**

## Apollo 11 Commentary

Following 102:27:14:
Neil spent 285 hours - 30 percent of his training for Apollo 11 - in various LM simulators other than the LLTV Buzz spent 332 hours in various LM simulators. They also spent 56 hours in briefings about LM systems.

Armstrong - "I would add, along that same line, that the time requirements necessitated that we accept the conclusions and recommendations of the crews that went before us. So, we did not spend an extraordinary amount of time on things that had already been done and had worked as expected. We focused a great deal of our attention on those things which had not been done before and which we would be expected to pass on to the crews behind us."

Following 102:46:23:
Armstrong - "I would say that the Lunar Module flew better than the LLTV - fortunately. However, it was a reasonable simulation of the Lunar Module, and it was the best we had. The full-mission (but stationary) Lunar Module simulator worked very well, but the real in-flight situation provided by the LLTVs provided a reality that was hard to duplicate in a fixed-base simulator."

Link to 1988 discussion of the LLRF, 'Wingless on Luna', that Armstrong gave at the Wings Club in 1988.

Armstrong - "What the LLTV gave you was not so much the seat-of-the-pants dynamics as the real-world visual. (Chuckling) That and the fact that, if you make a mistake, you can't hit the reset button."

From the Apollo 11 Technical Crew Debriefing, Section 24.22 Lunar Landing - LLTV, LLRF, LLTV's, and LMS
Armstrong - "For the type of trajectory that was required for us to fly (with a long manual flight at the end), the LLTV was a most valuable training experience. Like all simulations, it's primarily a confidence builder to derive the required information from the information that's at hand. In the flight situation, the information that I used in the landing was primarily visual. It was augmented by information inside the cockpit that Buzz relayed to me. I did very little gauge monitoring during the final descent, that is, below 300 feet. It is primarily an out-the-window

job, picking a suitable landing spot and getting into it. The full-scale simulations are the only ones that do this – the LLTV and the LLRF. I would have to recommend continuing them both, at least until we have a few more landings under our belt. I would suggest that more attention be given in the LLTV to changing your landing spot while you're in the trajectory."

Aldrin - "And how to deviate from an automatic trajectory and smoothly pick up what you want to do in the way of deviations."

Armstrong - "I believe the LLTV can do that job and do it safely. That means that you probably have to do a few more total trajectories than we did in preparation for this flight. I suggest that a dozen is a desirable number – a dozen lunar trajectories in the LLTV. It takes about half a dozen before you're comfortably flying on a lunar trajectory, and after that, a couple of different deviations to different touchdown areas. The LLRF lighting simulation was quite interesting, but in retrospect, it's not a very good simulation of the lunar lighting situation. In the flight, you see much more daylight, at least at our Sun angle (10-degree Sun angle). It was much more of a daylight landing situation than the (LLRF) simulation that was portrayed by the night lighting simulation at Langley Research Center."

Aldrin - "They essentially set up a situation where there was no available horizon. That certainly was available in the actual case."

Armstrong - "The LMS new model is really a fine addition to the simulator. If you could afford building a model for Apollo 12, so that their last 2 months of simulation would be going into the Surveyor site, then I think you would get a substantial improvement in your confidence level to get to the desired touchdown site."

Aldrin - "I think this is particularly true if they stick to the objective of going to that specific area. We have enough available information from the Surveyor itself to build that model.
Armstrong - "I know that's an expensive item to provide, but our experience with looking at the L&A of Site 3 indicates that you really can get a good understanding of that local area in your many landing simulations in the LMS."

Aldrin- "In looking back on the choices that I made with regard to my participation in landing simulations, I think they were generally correct. I don't think that I suffered by not being exposed any more to the LLTV. I think one session at Langley was worth the effort. I concentrated on manual use of the throttle and I think that's probably what future LMP's should concentrate on, also. I think Neil agrees that if we did have to execute a complete manual landing, it would probably best be done by the Commander concentrating on attitude control and voicing to the LMP what rate of descent and what changes he wanted. It appeared to be a very difficult task for one person to accomplish all of these. Whereas, when the tasks were split, and use was made of the instruments to manually control the throttle, and a fair amount of practice was made, use of that good performance could be anticipated by a manual throttle landing. For the most part, this can be done in the LMS."

## Apollo 12 Commentary

Following 110:33:56:
Conrad - "I think everybody agreed that the LLTV was very essential to a successful landing. One of the problems which we were talking about earlier at lunch is that you have to realize that the visual on the simulator was very bad. We had a plaster-of-paris lunar surface (called the L&A) and a B&W television camera that ('flew' to it). So you're looking at a flat, no-depth boob tube - a television - in the window. So, the last five hundred feet, if you were watching that out the window in the simulator, it wasn't any good. It just didn't really resemble the real world."

Bean - "It was a virtual image something or other. Which was a flat TV with some optics that..."

Conrad - "Tried to give it depth..."

Bean - "But it didn't."

Conrad - "It was the best they had at the time. We didn't have a moving-base simulator, either. (In more recent times, Shuttle crews have been able to train in simulators that move in response to crew inputs and, thereby, give much more realistic simulations.) So, the LLTV was critical, to get a real feel. And the reason Al made the comment about maneuvering is that the LMP's didn't fly the LLTV."

NASA built two LLRVs and three LLTVs. Three of these five vehicles were lost in accidents. Because of the jet engine, the LLTV was actually a less stable vehicle than the LM and, therefore, was harder to fly. For this and other reasons, it was decided that only people who absolutely needed the experience - mission commanders and their backups - would fly the LLTV. None of the LMPs ever flew one.

Conrad - "By the time I flew, Neil had jumped out of one LLTV (May 6, 1968) and at least one of our Ops pilots bailed out. (Actually two non-astronaut test pilots, Joe S. Algranti and Stuart M. Present, bailed out, on December 8, 1968 and January 29, 1971, respectively). (NASA Administrator) Dr. Gilruth, bless his soul, just worried to death that somebody was going to get bagged in an LLTV. And so, he asked everybody when they came back (from the Moon) 'Do you think it's necessary to fly the LLTV?' And, the feeling that I think Neil had and myself - and I'm quite sure the rest of the guys - was 'Yes, you really should go ahead and fly the LLTV.' But, having had the three accidents and having that one vehicle left, Dr. Gilruth asked the guys to figure out how many flights we got on a vehicle before we crumped one. And it turned out to be like 260 flights or something like that. To finish the training after the third accident, they had to fly 240 more flights; and, so, when Gene (Cernan, the Apollo 17 Commander) flew the last flight in his training, the thing went to the Smithsonian or whatever because nobody was ever going to fly that thing again as far as Gilruth was concerned. And he almost didn't authorize the training, see. And so, at least the early guys pushed very hard for everybody to continue flying it."

Bean - "I remember you talking about it when they asked you. And really pushing hard for it."

Conrad - "Al hadn't flown one, and that's why he made the remark when I started really maneuvering the thing around. Because you had big attitude changes up there, because you're in a low gravity field. He had seen that kind of a maneuver, probably, inside the simulator. But that virtual image display and the fixed base didn't really give you any feel for it. So, the first time Al really experienced that was at the Moon. And I just passed it off 'Yeah, I'm busy doing what I was doing.'!"

Bean - "We were all flying helicopters and you didn't maneuver a helicopter any where near like that. Up there, you really had to move the LM to maneuver it. So Pete got used to it and I was thinking helicopter kind of stuff. So, when you (Pete) suddenly maneuvered much more than a helicopter, it caught me by surprise. But to you, well, that's the way you do it. I think it's because, on Earth, you're supporting the weight with a certain amount of thrust. So, let's say you've got to knock off ten foot per second forward. You pitch up to a certain angle to do that and you get used to that kind of maneuver. You go on to the Moon; you've got one sixth the thrust to hold this same mass up and ten feet per second forward with that mass is the same as it was on Earth. But, in order to stop it (from moving forward) with one-sixth the thrust, you're going to have to pitch up a lot harder. So I think it's just strictly the fact that you're operating with less thrust than a helicopter for the same weight and the same momentum. So, in order to use it, you've got to get that thrust vector up higher faster or you're just never going to slow down the translations, or get one going and then stop it. When you think about it, it makes sense. But, at the time, it just seemed like 'God, what's he doing?' It felt to me like you were pitched too far (back), you know. And you probably were doing quite a bit because you've got to get it (pitched) up there to get the little ol' thrust vector to work."

Conrad - "That's right, you have to move it more to get the maneuver. So it looks really bad to you, although nothing serious is happening."

Bean - "It looked normal to you!"

[Conrad, from the 1969 Technical Debrief - "I think the manual control of the LM was excellent. The LLTV is an excellent training vehicle for the final phases. I think it's almost essential. I feel it really gave me the confidence that I needed. I think the (immobile) simulator did an excellent job in manual control and LPD training all the way down to the last couple of hundred feet. I think both devices worked very well together."

## Apollo 14 Commentary

Following 108:15:18:
Shepard, from the 1971 Technical Debrief - "The control of the vehicle, I thought, was good. Here again, of course, I did practice with the LLTV (Lunar Landing Training Vehicle), as well as the LLRV (Lunar Landing Research Vehicle), and in the LMS (Lunar Module Simulator). I felt completely comfortable and completely in control of the vehicle all the time."

## Apollo 15 Commentary

Following 104:42:48
Jones - "When Jim said 'You've got P66', is it fair to assume that you were looking out the window?"

Scott - "As I recall, I went out the window as soon as we got down there (that is, at pitchover). Everything inside is for Jim. For me to come in and go back out, really takes too much time. You know, I might comment on this part of it. Another objective we had, based on the previous flights, was to stay on a constant flight path - a constant rate of descent - and get it down. The previous flights, as I recall, had all leveled out high and then had come back down. And we looked at their trajectories, and it seemed to be a trend, that the guys would start stopping too soon and use up a lot of propellant, doing a stairstep thing. So one of the things that we trained on and thought about, was to keep it going and keep it coming down a constant flight path so that we could save gas for the hover, if we needed it. The stairstep appeared to be a trend that people got into because there's no definition on the ground. There's no runway. With the LLTV (Lunar Landing Training Vehicle), you have the runway and it's very easy to determine how high you are when you know how wide the runway is and how long it is. When you get to the Moon, there's no runway. There's nothing there to tell you how high you are; and I think the trend had been for people to start slowing up their rate of descent too soon - because, of course, you don't want to get too close, too fast, 'cause then you can't stop."

Jones - "When Jim said 'You've got P66', is it fair to assume that you were looking out the window?"

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Scott, from the 1971 Technical Debrief - "The LPD (Landing Point Designator) was real good. I felt we were heading toward the point for which the numbers were being read. Manual control on the vehicle was excellent. I think it was more positive than the LLTV. I'll make one general comment. I felt very comfortable flying the vehicle manually, because of the LLTV training, and there was no question in my mind that I could put it down where I wanted to. We landed exactly where I was headed. In spite of the fact that the rear pad was in a crater, that's just where I wanted to land. I think our horizontal velocities were zero lateral and I had about 1 foot per second forward to keep from backing into anything. That's exactly what I wanted. There was no tendency to overshoot in attitude or overshoot in the selection of the landing site. I think all of this was because of the time that I had to work with the LLTV."

In a 1995 letter, Dave commented that he may not have been aware of the crater in which he put the rear pad because "it was shallow and probably had no shadow".

Scott, from the 1971 Technical Debrief - "I guess I can't say enough about that (LLTV) training. That puts you in a situation in which you appreciate propellant margins and controllability (because the vehicle could fail and crash). I think the LLTV is an excellent simulation of the vehicle. I think if you had to move from one point to another, you could do it quite well. I would recommend an altitude of at least 150 feet so you don't get into the dust problem. I think dust is going to be variable with landing sites."

Jones - "It seems to me that Jim's giving you a lot more LPD angles than I remember other LMP's giving the Commanders. And he doesn't give you a first H-dot (descent rate) until 500 feet, which is just before you go into P66. You two had obviously worked this final part many, many times."

Scott - "Oh, yes. And I wanted as much from Jim as I could get. I mean, I was outside the window. Everything from inside the cockpit was from Jim. So I had a lot of sources of information. We did that on the launch, too. We had everybody with a role talking to me. And sometimes simultaneously with the ground. And I remember having learned this from Jim McDivitt. Because he did this back on Apollo 9. To sort out the voices and take the one you wanted, and to get as much data as you could possibly have without an overload. You can block out what you don't want to hear. So when Jim and I worked on this, I remember we worked on him giving as much as he could, because I wasn't going to do any talking. I was going to do the flying. I was going to do outside the window, and he was going to tell me what was going on inside. We were comfortable doing it that way."

Jones - "You had rate meters and the like around the window, but you were entirely out the window."

Scott - "Entirely out the window. Because, from the LLTV training, keep it steady and you'll land it. I knew I could land the machine if it would stay upright and the engine kept burning. And all the other things I had was icing on the cake. So if Jim could feed me all this information, that was even better."

Jones - "So, basically, down to 400 or 500 feet, the computer's controlling the descent rate and you're basically just telling it where you want to put it down. And, below 500 feet, you take over and control the descent rate."

Scott - "Which probably gets you into the discussion of why people didn't use an automatic landing, like Jim Lovell would have. Lovell would have, he said, let the automatic system go. I don't know if you've had any other discussions on this point, but there were a lot. Because the automatic system would probably have done very well."

Scott - "I worked the rationale out with Jim (Irwin). The guy on the right's got to have some input 'cause, if the guy on the left screws up, it's bad news for the guy on the right. You know, if you're riding in the back of an airplane or in the right seat of an airplane, it's a lot more uncomfortable than if you have hold of the stick. And there are a lot of stories about that that are kind of interesting. But we sort of worked it as a team, because I could get all that data. My feeling was, if I'm in the loop mentally I can respond more quickly than if I have to watch an automatic system and take over and then get my mind in the loop. So I was more comfortable in flying a manual descent than an automatic descent. Not that I thought that the automatic descent wouldn't work. It would probably work. But, if something goes wrong, I'm in the loop already. And my mental computer is already running at full speed so, if there's a hiccup somewhere, I'm already on top of it. Whereas, if you have an automatic hiccup, you got to decide what it is you do to get into the system. That's why, in my opinion, I would always make the lunar landing manually. Mainly, because it's a challenge; but also because you (the pilot) are already on top of it and you're reaction to a failure or a problem is going to be much quicker. We were asked, 'Why don't you land automatically? Don't you think the system will work?' Of course, I think the system would work. But on the other hand, I think we - as a group flying the machine, the PGNS, AGS, Irwin, and me, we're all flying that thing - I think we as a collective entity are safer and more efficient if there's a focal point. And I was the focal point. Jim fed things into my ears. The Moon fed things into my eyes, and I could feel the machine operating. I had never heard a comparison with other flights, because we all left when we got through, right? I was very comfortable with Jim giving me as much as he could give me."

Journal Contributor Mike Poliszuk notes "Scott talks extensively about the time he spent looking inside vs. outside the cockpit. Had the technology been available at the time, a heads-up display (HUD) - window projected or projected onto a helmet-mounted display - would have been useful. At the minimum the LPD could have been displayed directly for the Commander, so the LMP would not have had to read the numbers aloud. Other data, such as h, h-dot, lateral rates could also have been projected; and with proper software, this data could have been portrayed in some graphical format that integrated all needed data into a form easily interpreted by the Commander."

Jones - "One of the things that Jack and Gene talked to me about was working hard on the AGS, not only as an abort system, but as...I don't want to misquote them, but to have confidence that they could have landed with it if they had to. They say that mission rules were, if the PGNS went out, you abort back to orbit. But they said they slogged the AGS pretty hard - with the updates and the like - that they felt fairly confident that they would have had good enough information out of it to land."

Scott - "I'll give you two comments. I was around when McDivitt and Schweickart spent a good portion of their lives on the AGS on Apollo 9. And it was not as capable as the PGNS. It was exactly what it was supposed to be - an abort guidance system. It was not as capable as the primary guidance system. But, from a technical, physical point of view, it would probably give you, in retrospect, enough information to make a manual landing from on the order of 400 or 500 feet. Just like an LLTV landing. If you can land the LLTV, then you could probably land on the AGS, because it would keep the system running. But, on the other hand, on a lunar mission, A, management would not let you do that. If I were a manager, I would not let you do that, because it's just not built to do that. And, B, when Jim and I were in our mission, we didn't ever consider that; we didn't spend any time on it. We were involved in other things and...Not that it wasn't a good idea because, when Gene and Jack got to their turn, things were much more mature, and they could spend time looking at that. And it's a good idea they did. And I believe they're right. The AGS probably could get you down. Nobody'd ever let you do it, though."

Jones - "You guys had been through your landing, John and Charlie had been through theirs..."

Scott - "And, as long as something will keep that vehicle stable...The LLTV landings were manual landings, and the LLTV was a great trainer. I mean, boy, am I glad we had that, because it gave me confidence that I knew what I was doing on the Moon, and I didn't have to think about things. I didn't have to consciously program myself to do things. I was automatic. So, my feeling was, if you can land the LLTV, you can land a LM. And if the AGS will just keep the sucker straight, you can get it down, manually. But you're not going to do that, mainly because, if you lose the PGNS, you're not going to land. That's the way it is. So you go into it that way. One of the things we did do was to cut the rendezvous in half, Jim and I. And they used it on 14, because our experience on Apollo 12 enabled us, when we got to 15, we were already up on the curve."

"When you're in the (LMS) simulator - and I'm sure Gene and Jack did the same thing - after a while you need some variety. I mean, there are all the normal emergencies and you can do all that stuff. So let's see what else we can do. Jim and I worked on cutting the rendezvous by one rev and helped them develop a quick rendezvous. And we got that done early on in 15, so they used it on 14. But I'm sure Gene and Jack, when they got in there, went through all their stuff. They were up on the curve, so 'Let's see if we can land on the AGS.' Great idea. Sure, you probably can. But we didn't do that."

Jones - "The LLTV. It was a solo vehicle. You didn't have an LMP standing there next to you feeding you information of any kind. What kind of instruments did you have?"

Scott - "Essentially the same as on the LM. Same kind of descent rate and altitude."

Jones - "Instruments surrounding a window?"

Scott - "Let me see. Yes, it was as high a fidelity as you can build on the Earth. You know, we started out with four LLTVs and ended up with one (because three were lost in crashes). And, every time one crashed, the hue and cry from management was, 'Get rid of those damn things, what good are they?' But we (astronauts), as a group supported the idea a hundred percent because, again, you've got to do things as real as possible before you get into the lunar situation."

Scott - "I remember when Pete came back and I had a couple of conversations where I asked him, 'What do you think about the LLTV?' And he said 'Boy, that's the thing to have.' So, when my turn came, I was absolutely insistent. 'You've got to fly this thing.' I could probably have gone to the Moon and landed without doing it, but I certainly wouldn't have had the comfort or the confidence."]

Jones - "Was the LLTV more or less stable than the LM itself?"

Scott - "Well, in what way? You couldn't abort. You run out of gas and you crash. And it also put you on the line. And it also enabled you to stretch yourself. In other words, when I flew the

LLTV, I never landed it where I was supposed to land. When I got down to where I was comfortable I could go where I was supposed to go, I pushed myself on to a secondary landing point, so could learn how to do that. I never had to use it, but it was a great opportunity to push things out to the edge under a controlled situation, with supervision, with people watching you, on a normal day where you didn't have all these other things going on. So you could push yourself out there without taking a big risk. And that's why I thought it was a marvelous machine. Hell of a challenge. A tough thing to fly. Landing on the Moon: I don't care what anybody says, that's damn hard. I mean, that takes real aviation. That's flying! And I think all the things we got prepared us to do that. And I was very comfortable."

Jones - "If you look at the list of Commanders, six of the seven (Jim Lovell included) assigned to make landings had Navy training. Everyone but Dave Scott."

Scott - "You're one of the first people I've ever heard observe that."

Jones - "And they had carrier experience. And Gene told me that he thought landing on the Moon was easier than a night carrier landing"

Scott - "And I think he's probably right. But go ahead."

Jones - "Had you ever done anything like that and is the fact that there were six Navy-trained guys due to the luck of the draw or did the carrier experience have anything to do with it?"

Scott - "Luck of the draw. Absolute luck of the draw. On the other hand, I think that they benefited from their carrier experience, because I do think it's hard. I've never done it but, golly, I know those guys real well and Dick Gordon (who was a Navy flyer) and I rotated backup and prime, backup and prime and we live across the street from each other and I flew with Dick a lot. Dick and I have lots and lots of yarns, together, let me tell you. And I know that the carrier landings at night are hairy mothers. They're tough. And I think that was valuable experience for those guys and I'd wish I had it. And I think it might have been tougher for me to learn how to land the LLTV without having had the experience of carrier landings."

"And I agree with Gene. Not that I can make a comparison from personal experience. But I can tell you that landing the LLTV was lot harder than landing any airplane I ever landed. But, as for who got to go, that was luck of the draw. As you well know...People say, 'Why did they pick Armstrong first? Oh, he was a civilian.' No, it was luck of the draw."

Jones - "He was in the rotation."

Following 124:44:11:
Scott - "One of the problems getting close to launch date was trying to get everything in - to do everything the last day. Which you couldn't possibly do, because there were so many things. You wanted to run through all the important things the day before launch, but you couldn't; so they had to be prioritized. And I don't recall what the priorities were."

Jones - "Flying the spacecraft, I would imagine."

Scott - "Yeah, but that got cut off reasonably early, just because we had to get down to the Cape. 'Flying the spacecraft', to me, means flying the LLTV. The (fixed-base) simulator was easy. The simulator becomes pretty ho-hum after a while."

Jones - "That's interesting to know."

Dave made his last LLTV flights on July 2nd, three and half weeks before launch.

Scott - "And the value of the simulator, at this point, was in integrated simulations with Houston, not in the individual things, because we'd had so much with Jim and I running through procedures that it was coming out our ears by now. So, what we do is a tune up on landing the LM. If we need any training at this stage of the game, we're not ready. The last month, the last two months, in terms of LM simulator time was probably minimal. 'Cause, by then, we should have been up on the (learning) curve."

"But running it with Mission Control was very important, again, because of getting all the players involved up to the very last minute. You have to think of the rest of the team, in terms of the Control Center and the Backroom and whatever. And what you really want is those people involved the day before the launch. So you've got to look at the bigger picture of what you do the last day or the last few days. And, probably the most important thing is to have the team practice before you go. And, hopefully, the individual things, like flying the LM simulator...If we weren't ready two months before launch, we really hadn't done our job. Because we've had plenty of time for that."

Jones - "Especially having backed-up 12."

Scott - "Especially having backed-up 12. Now, the LLTV is a different thing because its a real-time, dynamic vehicle, so you want that as close to launch as you can."

Jones - "Did you get to fly the LLTV before the (Apollo) 14 launch."

Scott - "I flew it during 12, as the backup Commander, and I don't recall when I flew it last before the flight. Some time reasonably close (July 2nd). And we also had one final (geology) field trip, close to the launch (a visit to Gray Mountain, Arizona, on 25 June 1971). Again, get everybody involved, keep us tuned up geologically speaking. So the real challenge was packing everything in, but not having too much, and having enough leisure time to do some thinking and to sort of cool it before launch. You don't want to go out and run a marathon the day before you race a marathon."

Jones - "Two weeks before, maybe, but not the day before."

According the Apollo 15 Training Log, Dave started training for the mission on 9 December 1969, about a month after Apollo 12 flew. He made his first LLTV flight (since the end of Apollo 12 training) on 16 February 1970 and made a total of 15 flight up to 22 June 1970. Apollo 13 splashdown was on 17 April and, because of the need to assess the reasons for the explosion in the Apollo 13 Service Module, both Apollo 14 and 15 were going to be delayed for many months. Apollo 14 splashdown was on 9 February 1971, with the Apollo 15 launch scheduled for 26 July. Dave resumed flying the LLTV on 28 April and made 18 flights, with the last on 2 July.

Scott - "It's just like a football team or a basketball team. You've got to peak at the right time."

Following 102:46:23 (A11):
In response to a 1997 question about his experience with the LLRF, Apollo 15 Commander Dave Scott offered the following: "Ah yes, the LLRF -- what an experience! The LLRF was indeed a large Erector-Set structure at Langley (Research Center) that operated much as you indicated. It was intended to provide LLTV-type training without the risk and cost - although it must have cost a bunch! However, it was actually used very little compared to the LLTV for several reasons. I tried it several times and found it to be negative training, albeit well-intended. The major problem for me was the lag in response to control inputs. Even though they had some feed-forward loops and, at the time, some sophisticated control modes, the system could just not compensate for a vehicle swinging from a cable. Thus, the very short systems lag in a very dynamic and tight loop was just enough to confuse the human response -- which for LLTV-type flight was probably on the order of 0.2-to-0.5 seconds from input to expected output. It was an impressive-looking rig though! Should be a reasonable amout of documentation on the LLRF in the Langley files; and some of the old-timers should have some good stories,. It was very important to Langley (as were a number of other Apollo-support activities, such as docking), and the structure may even still be there!"

## Apollo 16 Commentary

Following 104:28:39:
Young, from the 1972 Technical Debrief - "When we redesignated to the south, we must have had 30 degrees of (left) yaw and took it back out. At that Sun angle, we could see the rocks (through the dust) all the way to the ground and I think that was a great help. From 200 feet down, I never looked in the cockpit. It was just like flying the LLTV (Lunar Landing Training Vehicle); your reference is to the ground outside. You had another thing that nobody has ever remarked about before, and that was the shadow. I really didn't have any doubt in my mind how far above the ground we were with that shadow coming down (that is, getting closer to them as they approach the surface). I had no scale of reference to the holes; but, with the shadow out there in front of you and coming down, it really takes all of the guesswork out of it. For that kind of Sun angle, if the radar had crumped, I don't think you'd have had a bit of trouble in just going right in and landing just like a helicopter. First, we could see the thing (rocks and other surface features) all the way to the ground; second, the shadow was right there to help you with the rate of descent. When Charlie says 'you stopped and you're hovering', there wasn't any doubt in my mind that I was hovering. I could look out the window and see that we're hovering just like a helicopter. We were well into the dust - maybe 40 or 50 feet off the ground - when we were doing that."
Following 104:30:46:
Young, from the Mision Transcript - ":Man, I could see the...all the way to the ground. Just like flying the LLTV. Piece of cake."

Apollo 17 Commentary> Following 112:59:25:

Cernan - "Although there is nothing quite like the real thing, flying the Lunar Landing Training Vehicle (LLTV) had been a step toward realism from "flying" the stationary simulators. In the LLTV you had your butt strapped to a machine that you had to land safely or you didn't make it. It still wasn't landing on the lunar surface, but it gave you a feel for what the actual landing would be like. Similarly, in simulator training we'd had a TV picture of a (large) model of the landing site that was good enough that, when we pitched over during the actual landing, I felt like I'd seen the landing site before. I won't say that I totally felt like I'd been there before, but I felt like I'd seen that valley before, three dimensionally. So it was a very comfortable feeling to know we were right where we expected to be."

Following 113:42:32:

Cernan, fromm the Mission Transcript - "Gordy, let me comment about the handling of the bird. After you once fly it (the LM) around in orbit a little bit, you get accustomed to the thrusters, and it came back to me quite a bit from (Apollo) 10, anyway. And you get a feel for acceleration and deceleration as well as the attitude-hold capability. And, really, the response, even with a heavy descent stage near the surface, is phenomenal. Responded exactly in the direction I wanted, held attitude very good. And, let me tell you, the LLTV(Lunar Landing Training Vehicle) played no small part in this landing as far as I'm concerned."

Schmitt - "As I recall, everybody was eventually supposed to go through LLTV training, but they were barely able to qualify all of the Commanders. All of us did get helicopter training as a precursor to the LLTV."

Cernan - "The reasoning behind giving only Commanders LLTV training, as best I can remember, was a combination of time, cost, and, quite frankly, safety. All the lunar module pilots wanted to fly the LLTV, strictly from a piloting point of view. When I was a lunar module pilot, I wanted to fly it. But, because we didn't have plans to land on Apollo 10, there wasn't any point in either Tom Stafford or I training in the LLTV; and, even for the actual landing missions, quite frankly, there was no need for LMP LLTV training. It would have been nice gravy to put on a chicken fried steak if the LMPs could have flown it as well as the Commanders; but, in reality, there was no need. There were two people to train for each flight anyway: the Commander and the Back-up Commander; and that pretty much took up all the time that was available. There were also some very real safety issues. We started out with four training vehicles, I believe, and we ended up with one. Joe Algranti (a NASA test pilot) ejected out of the first one. He was heading our aircraft operation before Neil ever flew the LLTV. And then two other people had to eject. So I was the last to fly the last one. It was a very unstable vehicle."

In all, Bell Aerosystems, Buffalo, NY built five LM trainers of this type for NASA. Two were an early version called the Lunar Landing Research Vehicle ( LLRV ). Neil Armstrong was flying LLRV-1 on May 6, 1968 when it went out of control. He ejected safely and the vehicle crashed. A later version was called the Lunar Landing Training Vehicle or LLTV and three were built. Two of these were lost in crashes on December 8, 1968 (LLTV-1 piloted by Algranti) and January 29, 1971 (piloted by Stuart M. Present). Both pilots ejected safely. The LLTV was a more accurate LM simulator and Gene is correct in saying that only one (NASA vehicle 952) was available for Apollo 17 training.

Cernan - "The LLTV gave us training in the critical final phases of the descent, from 500 to 700 feet on down. It had a J85 jet engine which, basically, maintained a constant thrust - based upon the weight of the vehicle - and took away 5/6th of the weight. That put you in a simulated lunar one-sixth gravity environment. You had sets of RCS thrusters, just like the lunar module, to control attitude; but, in addition, you had two other, vertically-mounted, hydrogen-peroxide-fueled 'lift' rockets that were capable of handling the extra one-sixth of the weight above the five-sixth that the J85 removed. They let you control how fast you went up or went down. To fly a descent, you'd use the lift rockets to fly yourself up to about five hundred feet. Then you'd start a forward trajectory and pick a landing point a few thousand feet down a runway. The key was to practice, and to get familiar with the dynamics of a six-degree-of-freedom machine. The more experience you got, the more you could displace yourself; or you'd give yourself errors; or, as you developed proficiency, instead of flying right straight down the runway, you could move over in the grass somewhere and put yourself in a position where errors were established before you started."

"The LLTV was inherently less stable than the LM itself; and we also had to contend with gusts of wind that could cause problems. But, LLTV training was very valuable because it really put your tail out on the line. It was not a simulator you could make a mistake in and then reset. If you made a mistake, you busted your ass, quite frankly. It also really brought home the uniqueness of the problems that you get with six degrees of freedom. By six degrees of freedom, I mean that not only could you roll, pitch, and yaw the vehicle and change your thrust direction because of the main engine, you could also use the RCS thrusters and move it laterally up, laterally down, laterally left, laterally right, laterally fore, or laterally aft. You had a combination of all those things to do when you landed a lunar module, and that is why the LLTV was so realistic. It was a great training device, one of a kind and probably never will be seen or used again. The 'flying bridge'. The ugliest thing in the world; but it was an ingenious idea and an ingenious design, and I don't know how else you could have ever put yourself in a one-sixth gravity flying environment, with rocket engines, here on Earth, and still have six degrees of freedom. Helicopters are just vertical flying machines, and they were nothing like this at all."

Also used in training and in the development of the landing systems was the Lunar Landing Research Facility - shown here with Neil standing in front of the LM mock-up. The facility consisted of a large, overhead gantry which allowed the cable-suspended LM mock-up to be moved forward and down - or up and back - in response to pilot input. The figure consists of a set of multiple exposures showing the mock-up as it comes in for a landing. A view from behind and one from the side show the vehicle approaching touchdown. Note that the 'craters' are painted on the flat tarmac. Both images are frames captured by Ken Glover from a 16mm film of a training session in late June 1969 with either Neil or Buzz as the pilot.

In 2002, I was reminded that the Apollo 15 Training Log shows that, on 24-25 March 1970, Jack was at Langley AFB using the LLRF. Although the Apollo 15 Prime and Back-up crews were not announced until 27 March 1970, the training log shows Jack's first Apollo 15 training session was a LM Radar Briefing on 27 October 1969. Dick Gordon, the Back-up Commander, didn't join Jack in training until 3 April 1970, following the conclusion of the Apollo 12 PAO tour.

Schmitt, from a 2002 e-mail - "As I remember, that was my only use of the LLRF at Langley and I had several runs during those two days. Originally, LMPs also were going to check out in the LLTV. Development and test delays and having the LLTV operational long enough to train CDRs, however, prevented this from happening."

"Al Shepard told me in January 1970 that I would soon be assigned to a back-up crew and that I should start stealing some simulator time. I had already been doing this for many months and just increased the level of activity to scheduling time whenever the MSC or KSC, CSM or LM simulators were available. In fact, this was the reason that I was at KSC rather than Houston right after Apollo 13 launched - the simulators were available. That meant that when the Apollo 13 explosion occurred, I immediately began to work with the KSC simulator operators to develop and test navigation and engine burn procedures we thought 13 would need as well as test those developed at MSC."

"The simulator operators at both MSC and KSC were great and spent a lot of time with me as I learned the various systems and subsystems as they were presented in the two cabins. I also scheduled a lot of time with the contractor training personnel that understood the details of the various CSM and LM systems. I worked alone until Dick Gordon, Vance Brand and I began to work as a crew, probably after Apollo 13 returned, the 12 crew was free of post-flight activities, and the Apollo 15 prime and back-up crews were assigned internally. April 1970 sounds about right as my memory is that we trained for 15 months for the July 1971 launch of Apollo 15."

Note added 13 December 2005: Journal Contributor Brian Lawrence adds that, based on unconfirmed but seemingly plausible postings to sci.space.history, "In December 1966 Deke Slyton assigned six guys to do the initial testing of the LLRV. They were the CDRs and LMPs of the early crews who might have been assigned to flights with an LM. They were Borman/Anders, Conrad/Williams, and Armstrong/Aldrin. Williams made one - possibly two - flights in February 1967 before the training was put on hold for a year. He died in an aircraft accident in October 1967. Starting in February 1968 the other five men got their chance. When Neil ejected from LLRV #1 (6 May 1968), he had made 21 flights while Pete had made 13. The other three (Borman, Anders, Aldrin) had made 18 flights between them. When flights resumed in June 1969, there was no time for any of the LMPs to fly the vehicle."

Following 118:31:01:

Cernan - "I had a firm idea in my mind about how I wanted to land. I wanted to bring that thing down as quickly as possible and then, when we got down within the 50 or 60 feet range, slow down to two or three per second and maintain two or three feet per second and a little forward velocity of a foot or so per second forward. You learned very quickly in the LLTV that if you tried to get it down at about one foot per second, all of a sudden you started hovering, or maybe you put a little bit too much thrust in and you started going up a little. So I tried to keep going down."

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