Rocket + Science = Dialogue

By Bruce Morris, Greg Sullivan, and Martin Burkey

It's a cliché that rocket engineers and space scientists don't see eye-to-eye. That goes double for rocket engineers working on human spaceflight and scientists working on space telescopes and planetary probes. They work fundamentally different problems but often feel that they are competing for the same pot of money. Put the two groups together for a weekend, and the results could be unscientific or perhaps combustible.

Fortunately, that wasn't the case when NASA put heavy lift launch vehicle designers together with astronomers and planetary scientists for two weekend workshops in 2008. The goal was to bring the top people from both groups together to see how the mass and volume capabilities of NASA's Ares V heavy lift launch vehicle could benefit the science community.

Ares V is part of NASA's Constellation Program for resuming human exploration beyond low Earth orbit, starting with missions to the Moon. In the current mission scenario, Ares V launches a lunar lander into Earth orbit. A smaller Ares I rocket launches the Orion crew vehicle with up to four astronauts. Orion docks with the lander, attached to the Ares V Earth departure stage. The stage fires its engine to send the mated spacecraft to the Moon.

Standing 360 feet high and weighing 7.4 million pounds, NASA's new heavy lifter will be bigger than the 1960s-era Saturn V. It can launch almost 60 percent more payload to trans-lunar insertion together with the Ares I and 35 percent more mass to low Earth orbit than the Saturn V. This super-sized capability is, in short, designed to send more people to more places to do more things than the six Apollo missions. That kind of heavy lift capability, the Constellation Program believes, would be a national asset potentially useful to endeavors other than human spaceflight.

Ames Research Center Director Dr. Pete Worden seized on ideas presented in some early papers and background discussions, recognized what heavy lift could mean to science, and volunteered to host a meeting at his field center of vehicle engineers, scientists, and payload designers. An organizing committee representing key organizations and players was set up to work out the details.

Participants now reflect that both the venue and format of the meetings were important to their success. Worden's "weekend workshop" format had already proved successful and was adopted for these important summits, one for astronomy, another for planetary science. Scheduling a weekend meeting was probably the only way to quickly bring together busy key managers and scientists whose calendars are always full. And it guaranteed the commitment of attendees. "As Pete likes to say, only serious people come to a weekend workshop," said Dr. Stephanie Langhoff, Ames chief scientist and head of the organizing committee for both Ares V workshops.

The first workshop April 26-27, 2008, was devoted to astronomy. Ares V designers from the Marshall Spaceflight Center spoke first on Saturday morning, giving an overview of the Constellation program and a detailed look at the Ares V and its capabilities. Astronomers followed in the afternoon, presenting eight concepts for observatories to study the universe in several regions of the electromagnetic spectrum. After a full day Saturday that ran into the early evening, the discussion continued unofficially at a nearby restaurant. Sunday was devoted to breakout sessions to determine what breakthrough astronomy might be enabled by Ares V and what kind of payload environments payload developers would need from Ares V.

The exchange was uniformly congenial, partly perhaps because the stakes were not very high. Ares V was early in its concept definition phase. The science community was making no commitment to a launch vehicle, merely invited to discuss the possibilities for a heavy lift launcher.

“It’s easy to be agreeable and collegial, because there’s no real money being spent,” mused Harley Thronson, associate director for advanced concepts and planning at Goddard Space Flight Center. “And astronomers recognize astronomy is a small field. We cannot be a significant player in how launch vehicles are designed. The commercial and military interests are much more important to determine how launch vehicles are built. Astronomy has to be opportunistic.”

Nonetheless, there is natural tension between the two groups, telescope designer Phil Stahl said. Astronomers want to launch ever bigger telescopes, which requires a large-volume payload shroud, while the Constellation Program, which is funding heavy-lift development, needs large launch mass. The fundamental problem, Stahl said, is that the larger shroud volume would reduce payload mass for the lunar mission, and the total height of the Ares V is limited by the height of the Vehicle Assembly Building at Kennedy Space Center. “Right now, neither side is in a position to say that they can modify their baseline designs,” Stahl said.

The basic question posed to scientists attending was what they could do if the existing limits on mass and volume were removed: Does Ares V enable breakthrough science not possible with any other launcher? What demands would large telescopes and planetary probes place on the Ares V and associated launch infrastructure? What technologies and environmental issues need to be addressed to facilitate launching such large payloads?

The advantage of heavy lift was easily illustrated. The revolutionary Hubble Space Telescope’s main light gathering mirror is 2.4 meters in diameter. The forthcoming James Webb Space Telescope is 6.5 meters across and relies on a complex system of folding mirrors for deployment. The Ares V 10-meter diameter shroud would permit a simpler, monolithic 8-meter aperture without complicated deployment mechanisms. The payload community made clear it would like the same environments and capabilities inside a heavy lift shroud as it has in the Space Shuttle and expendable launchers—cleanliness, venting, temperature control, continuous nitrogen purge, vibrations, G loads, acoustics, pad access, said Langhoff, who co-authored the final reports from both workshops.

“The purpose of the workshop was not so much to solve those problems, but to find where the problems lay,” Thronson said. “Early on, all sides need to know what the opportunities were, what potentially Ares V could deliver, and there were clearly some limitations, but before you solve them, you’ve got to find them.”

The planetary sciences workshop followed on August 16-17, 2008, again at Ames. The payload community's concerns were much the same as those of the astronomy community, plus a desire for accommodating capabilities such as radioisotope generators and a cryogenic escape stage. In the planetary sciences arena, the Ares V capability enabled deep space planetary sample return missions impossible on existing launch vehicles. Most tantalizing to Jet Propulsion Laboratory planetary scientist Tom Spilker was the idea of a sample return mission to Saturn's moon, Titan, to look for organic and pre-biological molecules. For such a mission, cleanliness from payload shroud encapsulation to the launch pad will be a hard requirement.

Stahl posed perhaps the most thought-provoking question of the workshops and led a breakout discussion on the subject of whether the mass and volume capabilities of Ares V might reduce payload complexity and thereby reduce the usual development and operational risks associated with big, so-called "flagship-class" space science payloads.

"We spend a lot of time making very small, high performance science instruments," explained Gary Martin, director of the New Ventures and Communications Directorate at Ames. "In theory, you could use more off-the-shelf components and not have to spend so much making science instruments so small, if you had the volume and mass margins of an Ares V."

Dan Lester, an infrared astronomer with the University of Texas at Austin, could easily visualize that theory becoming reality with heavy lift capability. His concept for an infrared telescope requires it to be folded like origami inside an existing launcher. Ares V would change that, he said.

"Now it requires a lot of pieces and a lot of folds and a lot of actuators and a lot of latches," Lester said. "And all these things have to work in order for your telescope to deploy. All the tests for all the folded stuff adds up to a quarter to a third of your cost—perhaps a billion dollars. The simpler you can make your telescope, the fewer things that have to be tested."

For scientists, it was an unusual chance to tell rocket designers what they need instead of designing to the constraints imposed by existing vehicles.

"It really is a sort of novel management tactic to do something like this, to get people who don't necessarily normally talk to each other talking," Lester said. "It's kind of a culture change for the science community to do stuff like that. We never thought about having the opportunity to give advice to people designing a new space transportation architecture. They weren't making any promises but they were saying, 'As we're doing this, we want to make sure we don't do something really stupid and design a launcher that works fine for going to the Moon, but has only 98 percent of the capability for launching big telescopes.' I think we came away with just a little better understanding. I think it was really very fruitful."

Participants in both the astronomy and planetary science workshops felt they gained useful insights that will help optimize a new national heavy lift capability. The Ares team's main performance standard is mass, Lester observed. It "opened their eyes" to learn that many of the astronomy ideas for Ares V used only 40-70 percent of the mass capacity but 100 percent of the volume. Ares Projects Planning Manager Phil Sumrall agreed, saying that, while lunar studies indicated an increase from 27.5 feet in diameter to 33 feet was desirable, the advantages to “other uses” helped finalize the decision at the expense of payload mass. Sumrall, notably, can now tick off payload requirements as easily as he does rocket jargon like “I_{sp}” (specific impulse) and “delta V”. Lester was heartened to learn that it wouldn’t be a huge obstacle to change the shroud, perhaps with modular components, to accommodate the largest scientific payloads.

During a breakout session at the planetary workshop, Spilker was surprised to learn that the Ares V Earth departure stage engine was designed to operate for 500 seconds and would be tested to that standard. “For a planetary spacecraft, you might need to back off on the thrust and run it for a longer time,” he explained. “Going in, I had no idea that was going to be a consideration. We started learning all the nuances of design that need to be thought about.”

There may have been some skeptical scientists in the audience, Lester said, but none who wanted to be left out if heavy lift becomes a reality. The workshop format ensured certain topics were surfaced and then allowed participants to explore them in detail.

“In some ways, it’s serendipitous,” Spilker mused. “Like anytime when you start a large project, it takes a while to wrap your arms around all the things that need to be done. Rather than 30 minutes for presentations and five for discussion, there was more time for open forum discussion. Then there was time for panel discussions and breakout groups to discuss in a less structured format various aspects. We had several breaks and lunches where we all stayed together. If you wanted to talk to somebody and didn’t talk to them, it was probably your fault. ”

Less tangible but perhaps more important impacts may be found in the business cards scientists and engineers exchanged during the unusual meetings.
”Now we know who to call if we have a question,” Sumrall said.

Electronic copies of the Ares V science workshop final reports can be downloaded from http://event.arc.nasa.gov/main/index.php?fuseaction=home.reports

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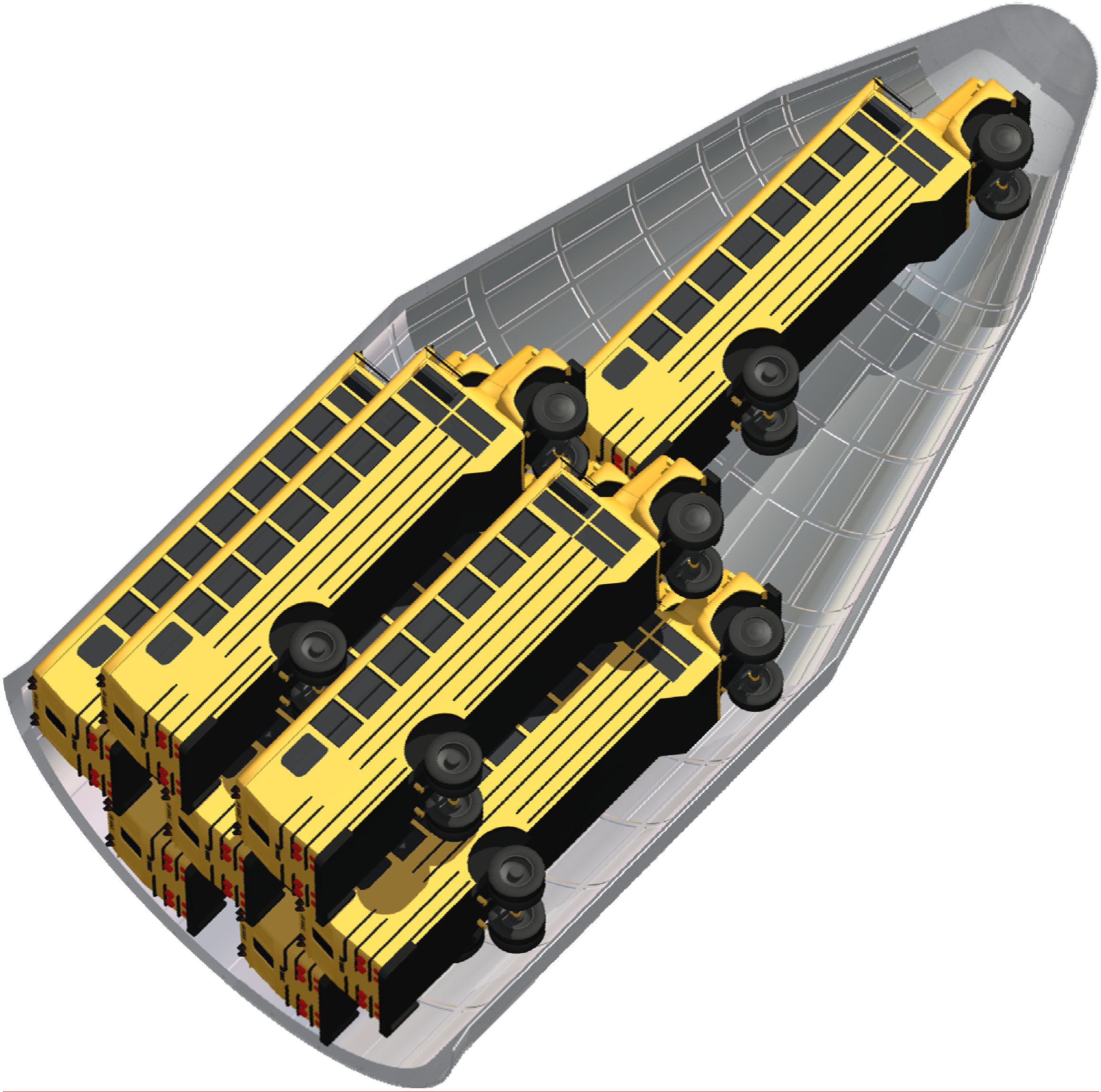


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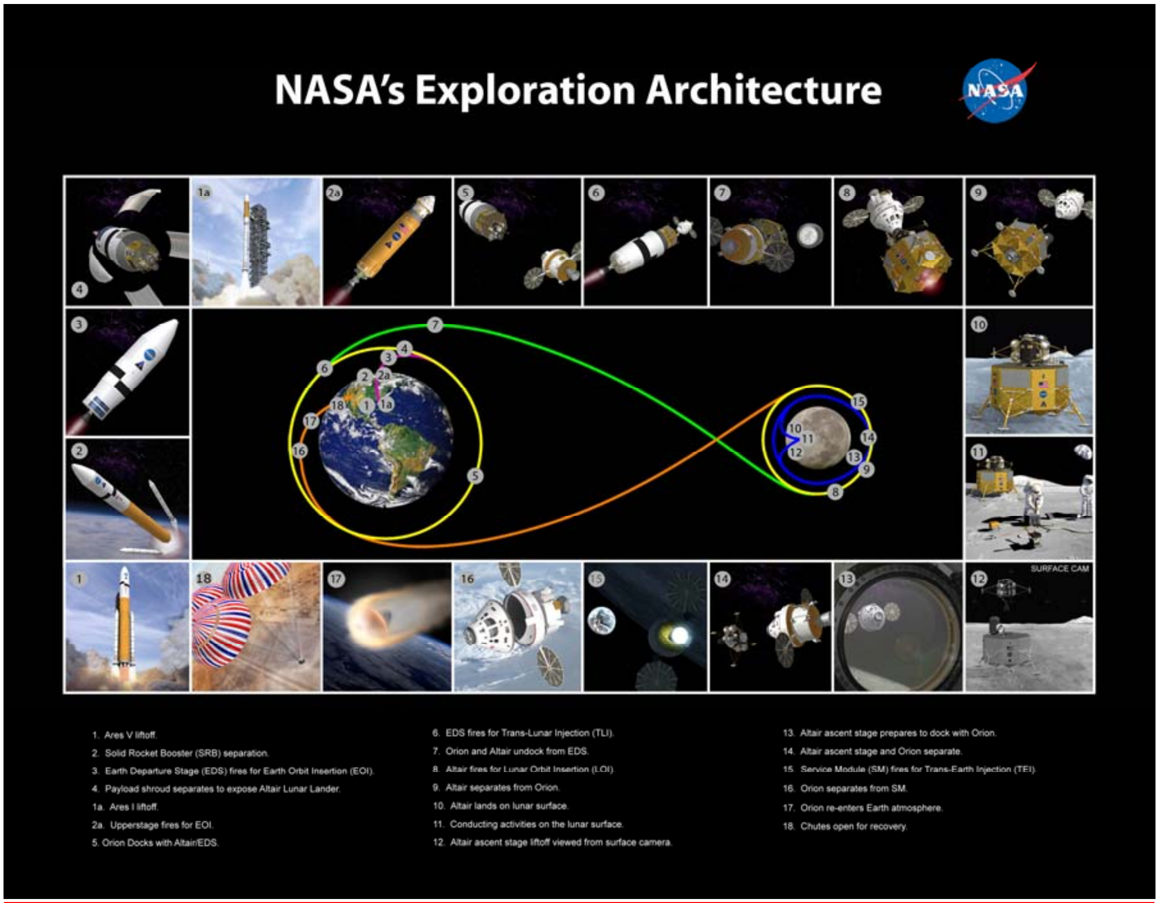
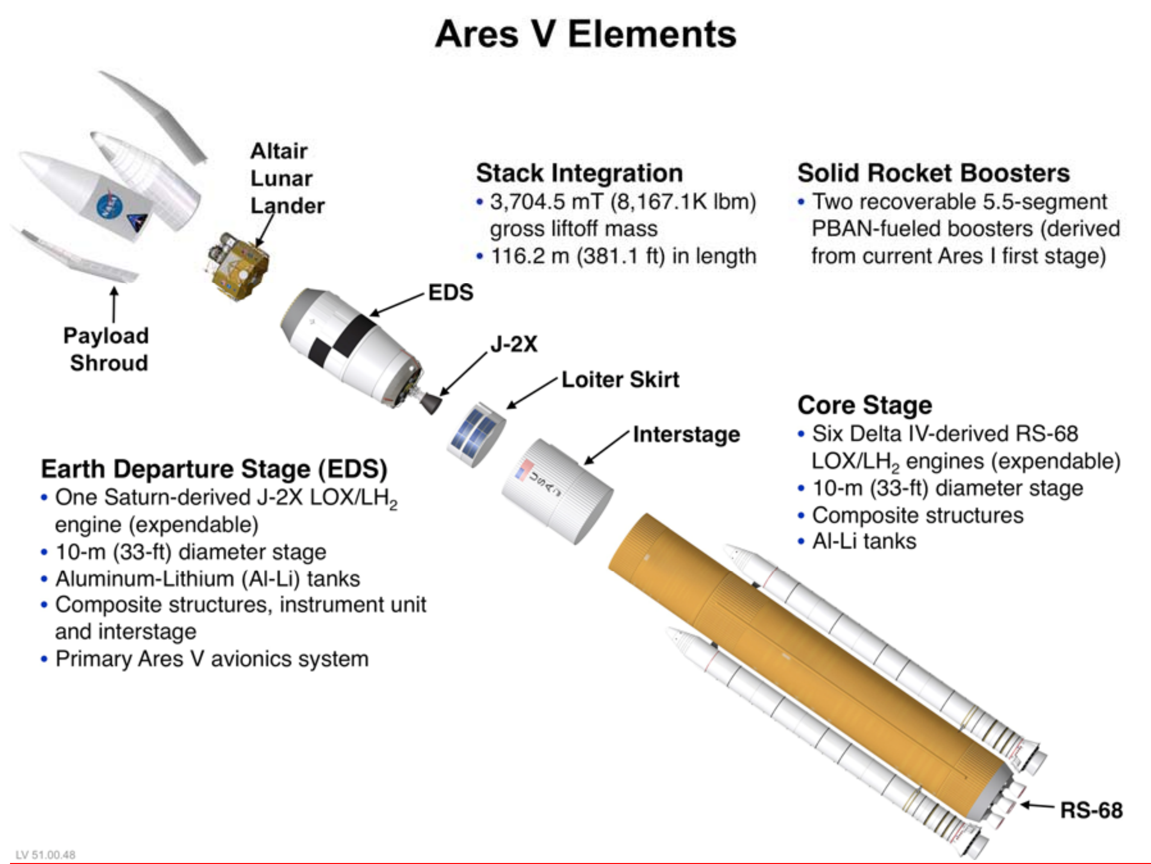

NASA's Exploration Architecture
SURFACE CAM
1. Ares V liftoff.
2. Solid Rocket Booster (SRB) separation.
3. Earth Departure Stage (EDS) fires for Earth Orbit Insertion (EOI).
4. Payload shroud separates to expose Altair Lunar Lander.
1a. Ares I liftoff.
2a. Upperstage fires for EOI.
5. Orion Docks with Altair/EDS.
6. EDS fires for Trans-Lunar Injection (TLI).
7. Orion and Altair undock from EDS.
8. Altair fires for Lunar Orbit Insertion (LOI).
9. Altair separates from Orion.
10. Altair lands on lunar surface.
11. Conducting activities on the lunar surface.
12. Altair ascent stage liftoff viewed from surface camera.
13. Altair ascent stage prepares to dock with Orion.
14. Altair ascent stage and Orion separate.
15. Service Module (SM) fires for Trans-Earth Injection (TEI).
16. Orion separates from SM.
17. Orion re-enters Earth atmosphere.
18. Chutes open for recovery.


Ares V Elements
Altair Lunar Lander
Payload Shroud
Stack Integration
• 3,704.5 mT (8,167.1K lbm) gross liftoff mass
• 116.2 m (381.1 ft) in length
Solid Rocket Boosters
• Two recoverable 5.5-segment PBAN-fueled boosters (derived from current Ares I first stage)
EDS
J-2X
Loiter Skirt
Interstage
Core Stage
• Six Delta IV-derived RS-68 LOX/LH_2 engines (expendable)
• 10-m (33-ft) diameter stage
• Composite structures
• Al-Li tanks
Earth Departure Stage (EDS)
• One Saturn-derived J-2X LOX/LH_2 engine (expendable)
• 10-m (33-ft) diameter stage
• Aluminum-Lithium (Al-Li) tanks
• Composite structures, instrument unit and interstage
• Primary Ares V avionics system
RS-68
LV 51.00.48


Composite Shroud
Altair Lunar Lander
Earth Departure Stage
LOX/LH_2
1 J-2X Engine
Al-Li Tanks
Composite Structures
Loiter Skirt
Interstage
Core Stage
LOX/LH_2
6 RS-68 Engines
Al-Li Tanks/Structures
2 5.5-Segment RSRBs