The Lurio Report

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Dragon Reaches ISS Despite Falcon Engine Shutdown, Altius, 'Blue' and XCOR News, Farewells

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Space Frontier Foundation Award for NewSpace Journalism

"There is so much new material out in the ether of space reporting that it is refreshing to receive a distinct and realistic assessment of events and themes in the industry. In those regards the Lurio Report nails it every time....an indispensable read."

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-- Christopher Stott, Chairman & C.E.O., ManSat LLC, <www.spaceisle.com>

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Contents:

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Quick Updates:

Altius Gains Contracts and SAA: Vol. 7, No. 7 (May 18) included a section on the status of Altius Space Machines based upon the 2012 Space Access Conference, entitled in part, "Lean Days and New Promise." Company head Jonathan Goff had told me that two research proposals had been "selected for contract negotiation, and we should be starting work on them later this summer." Recall that the Louisville, Colorado based firm's primary focus has been its Sticky Boom™ technology: A "Storable Tubular Extensible Member," or "STEM" unrolls into a rigid arm, at the end of which is a robotic hand including gripper pads that move to comply with the surface contours of a target. The pads adhere non-mechanically using any "resettable" adhesive.

Since mid-summer, Altius has released news of _*three*_ agreements (two contracts and a Space Act Agreement, SAA) that include work on technology research areas that were mentioned in that May Report. Among them were:

Compliance Control Development - Active force feedback to the boom deployer allows minimized initial contact forces, maximizing probability of object capture rather than it "bouncing" away; *'Gecko' Grippers* - Use of a resettable adhesive derived from work at JPL, an alternative to an electrostatic system; *Metal Matrix Composites (MMC); and Multi-DOF (Degree Of Freedom) STEM Arms, Tension-Stabilization* - To allow very long arms by using multiple deployable segments joined at nodes.

Both contracts are, "part of the DARPA Phoenix Program," though one is with the DARPA (Defense Advanced Research Projects Agency) itself, the other through a subcontract with JPL. Phoenix is aimed at lowering the cost of new military space communications systems by enabling retrieval and reuse of antennas and other components from defunct satellites in geosynchronous or "disposal" orbits.

The agreements are:

Single-DOF STEM Arm for Space Situational Awareness and Oscillation Damping - This contract with DARPA was announced on July 30.

Altius will engineer and integrate one of their STEMs, to be built by Roccor LLC, also of Louisville. At the end of the arm will be a camera/sensor suite to be developed by Ecliptic Enterprises, Inc. The hardware will be used by the University of Colorado, "to explore contact compliance control calculations and robotic control software necessary to damp out any unwanted oscillations in the target spacecraft."

Development of a Touch-To-Grasp-Gripper - Under the subcontract with JPL announced on September 19, Altius will work with the Lab to build a gripping tool using the synthetic 'Gecko' adhesion material alluded to above.

Space Act Agreement with NASA Langley Research Center - This non-reimbursable agreement to work on mission concepts and technology with NASA applications was announced on September 4.

Altius will combine NASA's manipulator expertise with its own technologies to develop a "Compact Stowable Manipulator" (CSM) for "highly-dextrous, long-reach operations." Real customer needs will inform the requirements for the CSM and its longer reach, multi-segment variants, which could extend in excess of 100 m. These systems may use tension wires for stabilization. Among applications are capturing satellites not designed to be, inspecting and repairing heat shields not directly visible to crews (e.g. at the back of a capsule), satellite

servicing, and the capture and release of "nano-scale" free flyers or payloads. Altius has conceived "Direct to Station" package delivery to the ISS.

In sum, the CSM is aimed at providing spacecraft with the capabilities of the Shuttle's manipulator arm - and more - in a much more compact package.

NASA's Office of the Chief Technologist (OCT) has recently awarded funds to Langely (under its portion of the SAA with Altius), for construction during Fiscal Year 2013 of a prototype single segment of a long-reach system.

Congratulations to Altius on concluding these agreements. The company's ideas, hardware and dedication display the creativity being provided by New Space firms of all sizes. (Recall that they won top prize at the NewSpace 2011 Business Plan competition.)

Stig B Flies, Is Recovered Properly...But: On October 6 Armadillo Aerospace's "Stig B" testbed rocket was launched from Spaceport America. The Spaceport's press release provided only the fact of the launch, but Clark Lindsey of NewSpace Watch and Doug Messier of Parabolic Arc gleaned a bit more data from tweets sent by Armadillo founder John Carmack.

One item was that the guidable-parachute landing system worked well. The other was that the vehicle aborted the flight at a relatively low altitude after detecting too high a sideways motion (ground speed). Carmack said that they hoped to "fix a couple things" then fly again shortly.

Correction to October 1 Issue: I have been advised that not all parties connected to the flight would attribute the previous Stig B launch delay to "red tape" related to the launch range.

Progress at Blue Origin, XCOR Aerospace and The Suborbital Advantage:
Blue Origin - Successful Thrust Chamber Firing, Pad Escape Tests and More - In October Blue Origin announced completion of two significant tasks under the earlier CCDev2 round of the NASA Commercial Crew Program (CCP).

Early in the month, the company fired at full power the combustion chamber for its new BE-3 liquid oxygen/liquid hydrogen (LOX/LH_2) rocket motor, which is designed to produce 100,000 lb thrust and be used in the company's "Reusable Booster System (RBS)" for orbital flight. See here under "Media" for the October 15 and other press releases and an image of the firing, which was conducted at the NASA Stennis Space Center (a direct link to their "Media" page does not seem to connect).

According to their original CCDev2 Space Act Agreement (SAA) with NASA (March 29, 2011) this "Thrust Chamber Assembly" test for the RBS risk reduction project was to use pressure-fed propellants.

On October 22, the company announced that they'd had a successful test the previous week (October 19) of a "pusher" abort system suitable for reusable vehicles. **They used a "full-scale suborbital Crew Capsule," stating that, "As part of an incremental development program, the results of this test will inform the design of the escape system for [our] orbital Space Vehicle."** The capsule reached 2,307 ft altitude using active thrust vector control and it came to a gentle touchdown under three parachutes, 1,630 ft away from its takeoff point atop a "launch vehicle simulator."

As well as the three images accompanying the press release, the company released a video of the test. That's quite a "kick in the pants" from the abort rockets, but one would definitely prefer it to being trapped atop a booster undergoing a catastrophic failure.

The same SAA document referenced above indicated further optional milestones culminating in a test where the capsule would first be accelerated by a rocket sled to "simulate maximum dynamic pressure during booster ascent" before performing a similar abort test. However, while two other firms received NASA funding for CCDev2 optional tasks, I don't believe that 'Blue' did. Of course, I nonetheless expect the company to use its own deep pockets to proceed with whatever following steps it deems necessary.

Brett Alexander of Blue Origin recently told Alan Boyle that the successor to the suborbital propulsion test module destroyed in flight in August 2011 will use a single hydrogen fueled engine instead of five fueled by kerosene; the module will be of similar size. Alan also reported that Aerojet supplied a solid fuel motor for the abort test.

XCOR Aerospace - Engine Fired From Within Lynx, Vehicle-Mounted Solar Observatory - Live-blogging October 18 from the International Symposium on Personal and Commercial Spaceflight (ISPCS) Clark Lindsey reported that XCOR COO Andrew Nelson had said that a Lynx main engine had been fired the previous day for the first time while mounted on the vehicle's fuselage and thrust structure. A flight weight pump fed LOX.

Incremental testing is key to XCOR's development process, and Andrew later told me that only one engine was used that time and that the fuel was pressure fed; so in the next step the fuel pump will be added. When results are shown to be satisfactory, a second engine will be mounted, fired alone and then with the first one (each pump set is designed to feed two engines at once). A similar sequence will follow for the other pair of engines before testing with all four firing at once.

Another instrument system taking direct advantage of the promise of low cost, repeatable flights using the new reusable suborbitals has joined the Atsa space telescope that I've discussed previously. In an October 22 release the Southwest Research Institute (SwRI) said that it will build the "SwRI Solar Instrument Pointing Platform (SSIPP)," with development phased to the operational progress of XCOR's Lynx. Initially it will take the place of the Lynx passenger seat; later versions will be mounted outside (presumably in the Mark III Lynx's payload pod) to allow viewing at wavelengths blocked by the cockpit canopy.

The SSIPP will be a miniature solar observatory, primarily aimed at providing a platform, "to enable spaceborne science and instrument development at a fraction of the cost of [traditional] unmanned sounding rockets." The optics will lock onto the image of the sun and provide steering data to the pilot to help maintain that lock. SSIPP development is one of 14 technologies using reusable suborbitals being funded by NASA's Space Technology Program, with awards ranging from $125,000 to $500,000.

Let's hope that such worthy efforts, on multiple scales, aren't victimized in coming budget cuts instead of NASA's massive pork "resources;" they so richly deserve it.

Baumgartner's Jump: One can't help but be awed by the determination of Austrian pilot Felix Baumgartner, who jumped from a balloon-lofted gondola at 24.2 miles altitude on October 14. At one point during the free-fall portion - during which he reached supersonic speeds - he was spinning fast and almost blacked out. (Ironically, he later expressed views of New Space and spaceflight as a whole that are utter nonsense.)

Kudos also to Red Bull Stratos for maintaining their sponsorship through the years of development. (They got a lot of good publicity, too.)

Given the press coverage and number of on-line viewers, the _*inspirational*_ value of the jump is certain, but I'm not so sure of other direct payoffs. In particular, some reporters have commented that the jump will eventually aid in creating safety measures for the crew and passengers of forthcoming sub/orbital human-carrying vehicles.

But the suborbital systems will be flying higher and (except at apogee) considerably faster relative to Earth, while the orbital ones will fly _*very much*_ faster all the time. So to varying degree a "bailout" from either system entails a lot more time in vacuum, then a lot more heating as one encounters the "sensible" atmosphere (when the air has started having one effect or another on a vehicle or object, dependent here on starting altitude and velocity).

Baumgartner jumped into what was essentially a vacuum and was careful to eliminate as much residual body motion as possible, yet he still encountered the spin problem. Jump from a greater hight, or add in velocities up to that for orbits, and the _*dynamic pressure*_ (dependent on speed as well as air density) could quickly amplify the tiniest motions into much wilder

gyrations than anyone could control before blacking out. You'd need something like control jets on your suit to damp out residual motion until reaching lower altitudes. And you'd need a Thermal Protection System (TPS) of increasing capability with increase of starting altitude and velocity.

Mr. Baumgartner's pressure suit was a variation on the ones used on the SR-71 spyplane and the Shuttle during ascent, with no such attitude control nor heat shielding. Developing those systems would require an iterative design and test program. While making no judgement on its relative priority, that fits into the *_category_* of technology work that may be difficult for a private enterprise to justify but that an agency like NASA could and should pursue. Instead, NASA has been diverted to wasting most of its money on pork.

Beyond inspiration, the major significance of the jump was that it was *_allowed to happen_* rather than forbidden by overprotective regulation. People who want to take risks should be allowed to do so as long as they understand the level of that risk, given that danger to uninvolved parties is essentially zero. But we have continually had to fight to ensure that such opportunities will be allowed for those who will fly on the new commercial sub/orbital vehicles.

We will never understand what is needed for *_best achievable_* safety without allowing significant flight rates and design variety; the only alternative is the perfect safety of perfect prohibition. Yet there is continual pressure for the fantasy of mandating by fiat and from day one an *_absolute_* safety. Ironically, this pressure is even greater when government's own professional astronauts are involved. The result is that the nominal leading-edge risk-takers have been highjacked to politicians' fears for their careers should our "hero-astronauts" (to use an old Soviet phrase) be harmed.

The unprecedented on-line viewership for Baumgartner's feat may testify that the public has not lost interest in seeing people taking considered risks in space. Perhaps the public is more open to the necessary risk-taking with the new commercial vehicles than some in Washington think.

The other major significance of the jump is that it foreshadows and may quicken the advent of an era when many private organizations can carry out new scientific and other space projects as first the low cost suborbital, then the orbital, reusable vehicles start to fly.

To Two Pioneers, "*Ave atque vale*":

Neil Armstrong - These remarks may be tardy, but remain strong.

I was more upset than I could have anticipated by the unforeseen death on August 25 of Neil Armstrong. Someone noted that without him only one of the six lunar landing crews remains intact (Apollo 16's).

He was emblematic of a time when risk was more expected in life, when coolness and clear thinking in the face of real danger was more celebrated than than the tripe too often esteemed today. His manual landing of the Lunar Module "Eagle" as its fuel was running out was previewed by a string of even more amazing demonstrations of steadiness in the face of mortal hazard. One example was saving himself and his Gemini 8 crewmate Dave Scott after their capsule had started spinning ever faster because of a stuck maneuvering jet.

His flying record in air and space, his place as the first human to step on another celestial body, was at least matched by the modesty, reserve and grace he showed after Apollo 11. Rather than exploiting his notoriety for personal gain, he stayed out of the public eye to a fault, teaching aerospace engineering back home in Ohio and serving on NASA advisory panels. I had the privilege to hear him speak about the X-15 program at the Next-Generation Suborbital Researchers Conference (NSRC) back in February (Vol. 7, No. 4, March 30). As we all do, he surely had faults; yet echoing what I said then, he truly was the Cincinnatus of spaceflight.

The New Space community was disappointed that he failed to understand that we must move beyond the cold war framework at NASA, but I suspect that he would have eventually changed his mind.

Finally: Somewhere inside of me, it will always be a summer's day in July 1969 when men were first setting foot upon the Moon, and a boy about to turn 11 years old thought that the wondrous future of his dreams had arrived…

Ray Bradbury - I must also pay tribute to Ray Bradbury, who died on June 5th. **We need extraordinary dreamers as well as extraordinary doers.**

He spoke in words compelling, beautiful and haunting beyond parallel of the need for humans to take the great leaps out into space. The rover Curiosity's landing site on Mars has been dubbed "Bradbury Landing."

The day in 1971 before Mariner 9 became the first craft to successfully orbit another planet, a forum was held at Caltech on "Mars and the Mind of Man." A book of the same title was later published based upon the discussion, with followup essays by the participants. Bradbury's ebullience and skills were on fine display, and while he'd called himself the "least scientific" of the participants at Caltech, his bardic sensibility endures better than anything based on the limited knowledge of Mars back them.

Sadly, with his death, now all but one (Bruce Murray) of the panelists - which included Arthur Clarke and Carl Sagan - are gone.

Until I came across this August article from "The Atlantic" I didn't know that there was film of that Caltech forum. Please watch the embedded excerpt of Bradbury reading his poem, "If Only We Had Taller Been." This recent discovery is an appropriate coda to it.

Personal Update: I'm presently scheduled for surgery in late November to relieve a partial sinus blockage. That seems to have been behind repeated illnesses earlier this year and perhaps previously.

I hope to be able to get out another Report before the procedure. Barring complications, the primary recovery period should be a couple of weeks or so, but it varies, so I will work on Reports then as I am able.

Thank you for your consideration.

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Dear Acquaintances,

- CRS Mission Succeeds But Engine Shut-Down Has Consequences -

Delivering to ISS Despite A Major Launch Incident

SpaceX's first regular supply flight to the International Space Station (ISS) under a Commercial Resupply Services (CRS) contract lifted off on schedule on Sunday night, October 7 at 8:34 pm EDT. The Dragon capsule atop the Falcon 9 booster was carrying nearly 900 lb of supplies to the ISS on "CRS-1" The Falcon's second stage also carried a prototype satellite, the first of the second-generation Orbcomm messaging constellation. After releasing Dragon, the stage's engine was to be restarted to boost the "OG2" into a 350 x 750 km orbit. Ultimately, the satellite was to circularize its orbit at the 750 km apogee altitude.

I didn't notice anything unusual while watching the live webcast of Falcon's powered flight, transmitted from ground-based and on-board cameras - except that the first stage's "burn"

seemed to go on longer than scheduled. I was out of contact with the web for a couple of hours after the Dragon reached orbit and deployed its solar arrays,

By the time I'd returned, people who'd reviewed the launch video in slow motion had seen, less than two minutes into the flight, a flare from one of the first stage engines, followed by smoke and debris. Despite some initial guesses, the engine had not exploded. **The next day SpaceX confirmed that an "anomaly" had led to automatic shutdown of one rocket motor, after which the vehicle computed a new ascent trajectory using the remaining eight.** That was evidently the reason for the longer firing time that I'd not given close attention; despite my warnings not to take another flawless flight for granted, I'd virtually fallen into that trap myself.

One must emphasize that the Falcon's _*primary*_ mission of delivering Dragon to orbit so it could reach the ISS was achieved despite the engine shutdown. Dragon performed well, berthing to the ISS with the aid of the station's robotic arm, then the crew opened the hatch ahead of schedule. During the combined COTS2/3 test flight last May there had been a minor issue with reflections from the ISS interfering with the primary LIDAR (laser - radar) unit used on approach, but this did not recur (see Vol. 7, No. 8, June 11, 2012). Dragon departed the ISS and landed in the Pacific on October 28, carrying some 1,673 lb of return cargo, including refrigerated scientific samples.

"Engine Out" Uncertainty, Investigation and The Updated Falcon

The cause of the engine problem leading to shutdown and some of the follow-on events are evidently not yet entirely clear. SpaceX released several updates about the matter in the days after the incident, but review and detailed interpretation of raw data can take some time. Garrett Reisman, Commercial Crew manager for SpaceX, indicated that there was a "huge" amount of that data, as Clark Lindsey reported on October 18 from the ISPCS (International Symposium on Personal and Commercial Spaceflight). Company spokesperson Katherine Nelson underscored that in an email exchange.

The most detailed understanding of the incident might unavoidably require knowledge of proprietary SpaceX design details. In a phone conversation on October 12, NASA Johnson Space Center Public Affairs Officer (JSC/PAO) Josh Byerly noted that commercial operations come with limits on what can be publicly discussed.

That noted, given SpaceX's prominence as one of the top "faces" of New Space and _*the*_ top one for the NASA Commercial Crew Program (CCP), the company certainly knows that alleviating concerns will require as much openness as possible.

No level of openness and reasoned explanation will be adequate for some of CCP's opponents, because they don't understand - or don't want to understand - the positive changes of which it has been emblematic. The Falcon's engine incident on CRS-1 could be tossed into the witch's brew of policy manipulation and political chicanery that will heat up as new budget constraints loom. As I stated on October 1, "If [a mishap] occurred, the 'usual suspects' would of course unfairly jump at it to attack the validity of all New Space as well as SpaceX, CRS and the [CCP]."

So I'm happy that Congress is officially out of session until after election day.

The positive aspect of the launch anomaly is that SpaceX has now demonstrated in flight that, as designed, the Falcon can reach orbit with an "engine out" condition. Indeed, the vehicle is has been designed to cope with up to two forced engine shutdowns and still reach orbit. As the company noted in its update of October 8, "No other rocket currently flying has this ability ...[and] Falcon 9 shuts down two of its engines to limit acceleration to 5 g's even on a fully nominal flight."

An overview of the sequence of events of the incident was given in that October 8 statement:

"Approximately one minute and 19 seconds into last night's launch, the Falcon 9 rocket detected an anomaly on one first stage engine. Initial data suggests that one of the rocket's nine Merlin engines, Engine 1, ***lost pressure suddenly*** *and an engine shutdown command was issued.* ***We know the engine did not explode, because we continued to receive data from it. Panels designed to relieve pressure within the engine bay were ejected to protect the stage and other engines.*** *Our review of flight data indicates that neither the rocket stage nor any of the other eight engines were negatively affected by this event,"* [all emphases mine].

From the press kit for the flight, "maximum dynamic pressure" (or "max q") on the rocket was scheduled at 1 min, 25 sec into flight. Shields surround each engine core to prevent a catastrophic event such as pump disintegration from harming the other ones, but given the comment about "relieving pressure" I don't think these are the panels referenced. It also sounds like the panels ejected were automatically commanded to do so; alternatively, the ambient pressure differential could have caused the ejection by mechanical design.

Because of the size, shape and number of debris seen in the video, some suggested that they included the ripped-open engine bell of the rocket motor. With cutoff of combustion and thus of gas accelerating out of the bell, the pressure on its inside surface would be much reduced. Particularly at maximum pressure conditions _*outside*_, the pressure imbalance might have caused the bell to be ripped apart. But the October 8 statement (supplemented by a query to Ms. Nelson) appeared to eliminate such a notion.

On October 11 SpaceX announced that a joint NASA-SpaceX "CRS-1 Post-Flight Investigation Board" had been formed to "methodically analyze all data in an effort to understand what occurred to engine 1 during liftoff of the CRS-1 mission on Sunday, October 7." Ms. Nelson told me on October 18 that, "We will release the members of the investigation panel as soon as all members have been completely solidified."

Finally, as previously indicated, there is only one more flight scheduled before SpaceX starts flying the upgraded Falcon 9 "v1.1" exclusively. That vehicle will use the new, more powerful but simplified Merlin 1D engines. So the results of the Board's investigation may not be applicable to to the newer version. But analysis of what happened on October 7 remains important not only because of that last scheduled flight of the Falcon 9 "v1.0," but because the investigative exercise could provide valuable broader insights.

Note: The first stage version of the Merlin 1D executed its first full duration static firing of just over three minutes in McGregor, Texas this past June; by the end of September, Elon Musk had twittered that "Vac[uum]" version - i.e., for upper stages - was in testing.

Orbcomm Satellite Achieves Main Goals Despite Curtailed Life

As noted, the secondary payload on the CRS-1 flight was the prototype Orbcomm OG2 satellite. In Vol. 7, No. 1 (January 9) I mentioned that Orbcomm and SpaceX had decided to deploy it on this mission. But NASA restrictions precluding even a remote possibility of hardware becoming a hazard to the ISS added risk to Orbcomm's opportunity.

The adjustments to allow primary payload delivery after the first stage engine shutdown resulted in slightly less liquid oxygen than normal remaining in the second stage after the primary burn. After Dragon is released, it uses its own thrusters to climb to and rendezvous with the ISS, the altitude of which varies continuously with variable atmospheric drag effects and reboosts. (For example, it was given as 383 km in the mission press release, but from here it appears that the mean number was actually around 415 km in early October.)

On October 10, SpaceX released a statement that given the required compensation for the engine anomaly, "the liquid oxygen on board [the second stage] was only enough to achieve a roughly 95% likelihood of completing the second burn" to put the OG2 into a 350 x 750 km orbit, rather than the 99% probability required by NASA. So the OG2 was released into a 203 x 323 km orbit.

With that low perigee, atmospheric drag would soon cause it to reenter. By October 11 it had, and Orbcomm issued a press release - which, nonetheless, was titled, *"OG2 Prototype Hardware Functionality Verified Prior to Deorbit."* The text stated:

*"**Notwithstanding the shortened life of the OG2 prototype, the OG2 program engineering teams from ORBCOMM, Sierra Nevada Corporation and Boeing made significant strides in testing various hardware components** ... These verification successes achieved from the single prototype satellite validate that the innovative OG2 satellite technology operates as designed before launching the full constellation of OG2 satellites."*

In the same document Orbcomm stated that it was filing an insurance claim valued at up to $10 million for "total loss of the OG2 prototype," while adding that, "We appreciate the complexity and work that SpaceX put into this launch ...[it] has been a supportive partner, and we are highly confident in their team and technology." That same day, as recounted in this article from Space News, SpaceX noted that Orbcomm knew the risks going in, "underst[anding] from the beginning that the orbit-raising maneuver was tentative. They accepted that there was a high risk of their satellite remaining at the Dragon insertion orbit."

The majority of the satellite constellation was always intended be sent to orbit in multiple groups as primary Falcon 9 payloads, precluding the NASA restrictions that resulted in the rapid loss of the first OG2. In that January 9, 2012 issue of this Report, I referenced a December 2011 press release saying that after the CRS-1 flight, another two OG2s would be launched to "high inclination" orbits, also as a secondary payload. But the Orbcomm October 11 release appeared to indicate that there would not be such a flight, saying that the company now, "can focus on completing and launching the OG2 satellites as the primary mission payloads on two planned Falcon 9 launches, the first in mid-2013 and the second in 2014, directly into their operational orbit[s]." SpaceX informed me that only Orbcomm can state whether they still plan another "secondary" launch or have disposed of that earlier plan. I have sent an inquiry.

Conclusions - An 'Accidental' Positive?

To wrap up:

-- The demonstration of the capability to deliver the *_primary_* payload with "engine out" conditions may on balance improve confidence among SpaceX's costumers. Of course, at times there will be restrictions peculiar to being a *_secondary_* payload;

-- If the investigation board finds that the potential for a similar engine problem carries over to the Merlin 1D (i.e., the Falcon 9 v1.1), a question will be how long will it take to eliminate that problem, and how that process will affect longer term flight schedules;

-- As Rand Simberg at Transterrestrial Musings has pointed out, implications of the root cause of the anomaly are amplified for the second stage, which has only one Merlin engine;

As always, whatever the demonstrable flight and investigation results, lack of "perfection" may be used as a blunt instrument against SpaceX and other New Space ventures. But their collective progress is essential if *_NASA_* is to be a meaningful future contributor to human spaceflight.

Yours very truly,

Charles A. Lurio, Ph.D.

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