“ASSESSING THE OPTIONS OF THE AUGUSTINE COMMITTEE FOR HUMAN SPACEFLIGHT”

September 28, 2009

SPACE POLICY INSTITUTE

THE GEORGE WASHINGTON UNIVERSITY
THE ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS

Assessing the Options of the Augustine Committee for Human Spaceflight

Scott Pace
Director, Space Policy Institute
George Washington University
Washington, D.C.

28 September 2009

Space Policy Under Review

- New Administration efforts
  - Space Posture Review (Defense)
  - Augustine Committee (NASA)
  - Presidential Study Directive (NSC-led)

FY2011 budget proposals in work along with the outcome of latest Quadrennial Defense Review

2004 National Goals to Directives to NASA

- ✓ Complete the International Space Station
- ✓ Safely fly the Space Shuttle until 2010
- ✓ Develop and fly the Crew Exploration Vehicle no later than 2014
- ✓ Return to Moon with goal of 2015 and no later than 2020
- ✓ No later than 2008, begin a series of robotic missions to Moon
- ✓ Develop supporting innovative technologies, knowledge, and infrastructures
- ✓ Promote international and commercial participation in exploration
- ✓ Aggressive in-situ resource program and robust precursor program
- ✓ Sustained human presence on Moon for national preeminence, scientific and economic purposes, leading to Mars and other places

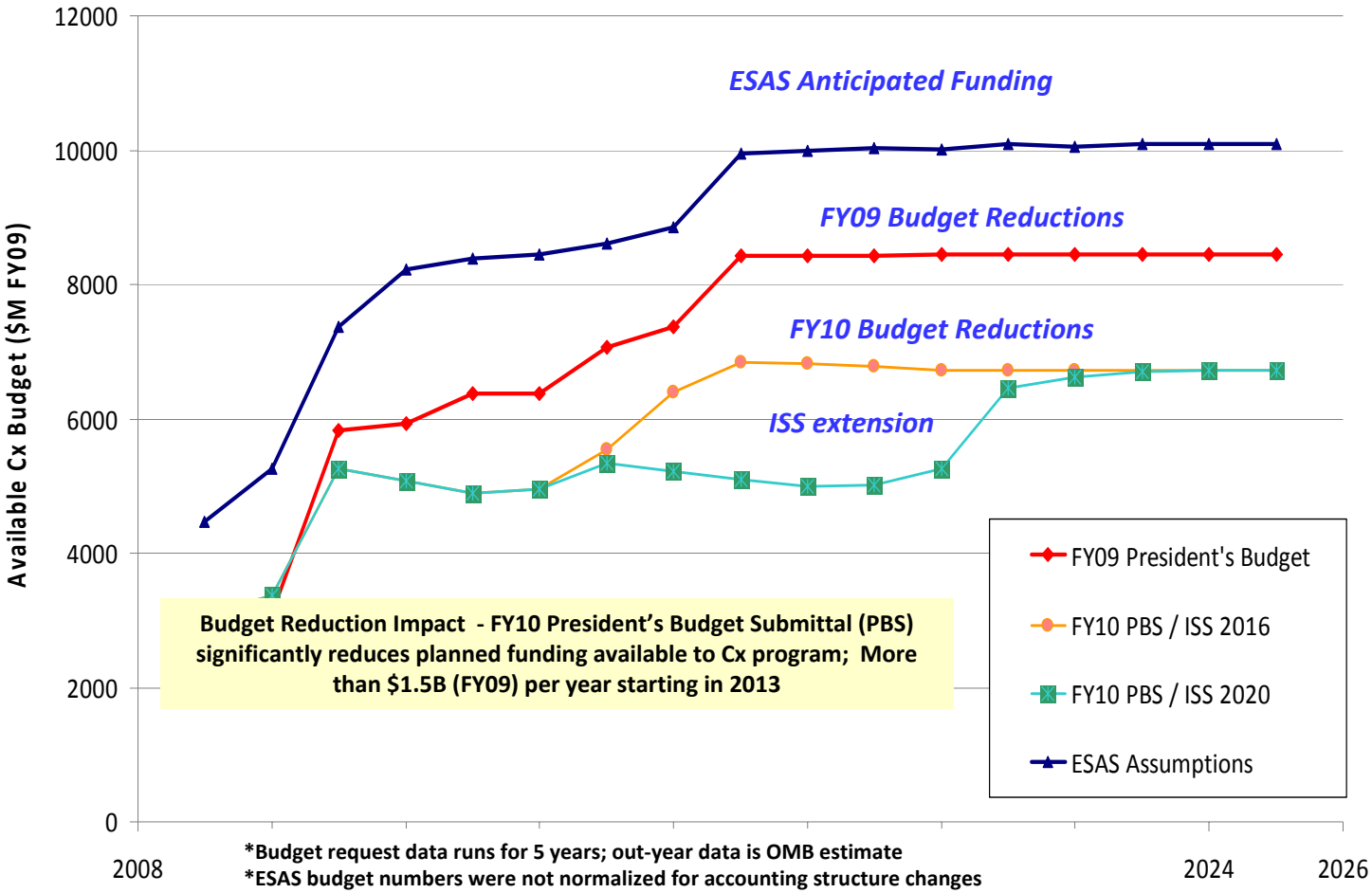
$3B Out-year NASA Budget Gap Concentrated in Exploration

Budget Authority ($ millions)	FY 2008 Actual	FY 2009 Enacted	FY 2010*	FY 2011*	FY 2012*	FY 2013*	FY 2014*
FY 2010 President's Budget Request	**3,299.4**	**3,905.5**	**3,963.1**	**6,076.6**	**6,028.5**	**5,966.5**	**6,195.3**
Constellation Systems	2,675.9	3,433.2	3,505.4	5,543.3	5,472.0	5,407.6	5,602.6
Advanced Capabilities	623.5	472.3	457.7	533.3	556.5	558.9	592.7
FY 2009 President's Budget Request	**3,143.1**	**3,500.5**	**3,737.7**	**7,048.2**	**7,116.8**	**7,666.8**	**-**
Constellation Systems	2,471.9	3,048.2	3,252.8	6,479.5	6,521.4	7,080.5	-
Advanced Capabilities	671.1	452.3	484.9	568.7	595.5	586.3	-
Total Change from FY2009 President's Budget Request	**156.3**	**405.0**	**225.4**	**-971.6**	**-1,088.3**	**-1,700.3**	

***Following the human spaceflight review, the Administration will provide an updated request for Exploration activities reflecting the review's results.**

										Projected at 2.4% inflation		
	FY 2004	**FY 2005**	**FY 2006**	**FY 2007**	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	
Projected: FY 2005 Pres Budget	15,378	16,244	17,002	17,815	18,001	18,034	18,463	18,777	19,267	19,729.4	20,202.9	
% change from previous year		*5.6%*	*4.7%*	*4.8%*	*1.0%*	*0.2%*	*2.4%*	*1.7%*	*2.6%*	*2.40%*	*2.40%*	
					FY 2008	**FY 2009***	**FY 2010**	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	
Projected: FY 2010 Pres Budget					17,401.9	18,784.4	18,686.0	18,631.0	18,613.0	18,607.0	18,858.0	
% change from previous year						*7.9%*	*-0.5%*	*-0.3%*	*-0.1%*	*0.0%*	*1.3%*	
*includes Recovery Act												
												total FY10-14
Nominal difference between FY05 and FY10 requests							*223.0*	*-146.0*	*-654.0*	*-1,122.4*	*-1,344.9*	-3,044.3
					FY2008 Act	**FY2009 En**	**FY 2010**	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	
Projected: FY 2010 Exploration Budget					3299.4	3905.5	3963.1	6076.6	6028.5	5966.5	6195.3	
FY 2009 Exploration Budget Request					3143.1	3500.5	3737.7	7048.2	7116.8	7666.8		total FY09-13
Change from FY2009 President's Budget Request					156.3	405	225.4	-971.6	-1088.3	-1700.3		-3,129.8

Projected Constellation Program Funding has seen Significant Reductions since ESAS



Budget Proposals are Policy

- Between the FY2005 budget request when the Vision for Space Exploration was announced and what was actually appropriated in FY08, there was a cumulative total of **$11.7B** in reductions ($3.9 billion) and costs absorbed ($7.8 billion, primarily for Shuttle Return to Flight and to complete assembly of the International Space Station) within NASA's budget between FY05-10.
- Congress provided an additional $1 billion for NASA in FY09 recovery funds, including $400M for Exploration, to which the Obama Administration allocated $90M for COTS from these Exploration funds.
- The Administration requested $18.686 billion for NASA in FY2010, a $904 million increase or slightly over 5%. This is helpful in the transition years now underway but the additional funding does not accelerate Orion/Ares I.
- FY2010 budget proposal had **$3B** less in out year budget for Exploration. NASA's budget for FY2011-2014 does not keep up with inflation – assuming inflation is greater than 1.36% This represents a **$10.7B** difference for Exploration in the seven years of FY2014-2020 if continued.
- Operating Shuttle into 2011 for the current manifest may cost $2B and operating the International Space Station through 2020 may cost an additional $15B for a total of **$17B** in additional burden if there is no supplemental for NASA. This would likely impact to Exploration even further.

Augustine Options

	Budget	Shuttle Life	ISS Life	Heavy Launch	Crew to LEO
Constrained Options					
Option 1: Program of Record (constained)	FY10 Budget	2011	2015	Ares V	Ares I + Orion
Option 2: ISS + Lunar (constrained)	FY10 Budget	2011	2020	Ares V Lite	Commercial
Moon First Options					
Option 3: Baseline - Program of Record	Less constrained	2011	2015	Ares V	Ares I + Orion
Option 4A: Moon First - Ares Lite	Less constrained	2011	2020	Ares V Lite	Commercial
Option 4B: Moon First - Extend Shuttle	Less constrained	2015	2020	Directly Shuttle Derived + refueling	Commercial
Flexible Path Options					
Option 5A: Flexible Path - Ares Lite	Less constrained	2011	2020	Ares V Lite	Commercial
Option 5B:Flexible Path - EELV Heritage	Less constrained	2011	2020	75mt EELV + refueling	Commercial
Option 5C: Flexible Path - Shuttle Derived	Less constrained	2011	2020	Directly Shuttle Derived + refueling	Commercial

Some Underlying Policy Issues

- From Mike Griffin's testimony 15 September 2009:
  - whether or not there is a need for independent U.S. government human access to space, and if not, the identification of those entities upon which we are willing to depend for such access;
  - whether or not it is in the larger interests of the United States to invite international partnerships in regard to capabilities which are on the so-called "critical path" to a desired common goal;
  - the degree to and roles in which the U.S. government should foster the development, and embrace the capabilities, of "commercial space" in the furtherance of national goals;
  - the proper role of NASA in guiding the human expansion into space, and in particular NASA's disparate functions as 'innovator and technology developer' vs. 'designer/developer/smart buyer' of new systems, and 'system operator' vs. 'service customer'.

- Major options are: 1) add money back, 2) change goals, 3) take more risk
  - Add $3-4B per year to maintain exploration program and extension of ISS operations
  - Defer exploration beyond low Earth orbit -- similar to the 1996 national space policy
  - Plan for commercial crew service prior to demonstration of commercial cargo capabilities and independent of private sector financing. Accept risk of longer reliance on the Russians, likely need to waive or drop some human flight rating rules, and industrial base impacts. Accept lack of internal NASA systems engineering capability going forward and likely workforce loss.

- Will NASA request and get an over guide in the FY2011 President's Budget?

What is the Future of Humans in Space?

1. *Can humans "live off the land" in space and function independently of Earth for long periods?*
2. *Are there economically useful activities in space that can sustain human communities in space?*

	Nothing commercially useful	Commercially sustainable
Live off the land	Antarctica	Settlements
Cannot live off the land	Mt. Everest	North Sea oil platform

See alsoHarry L. Shipman "Humans in Space: 21st Century Frontiers"

- We don't know which of these outcomes represents our long-term future. Advocates and skeptics may believe one outcome or another is most likely, but no one actually knows.
- Options that help us answer these questions more effectively should be preferred over those that don't.

“ASSESSING THE OPTIONS OF THE AUGUSTINE COMMITTEE FOR HUMAN SPACEFLIGHT”

September 28, 2009

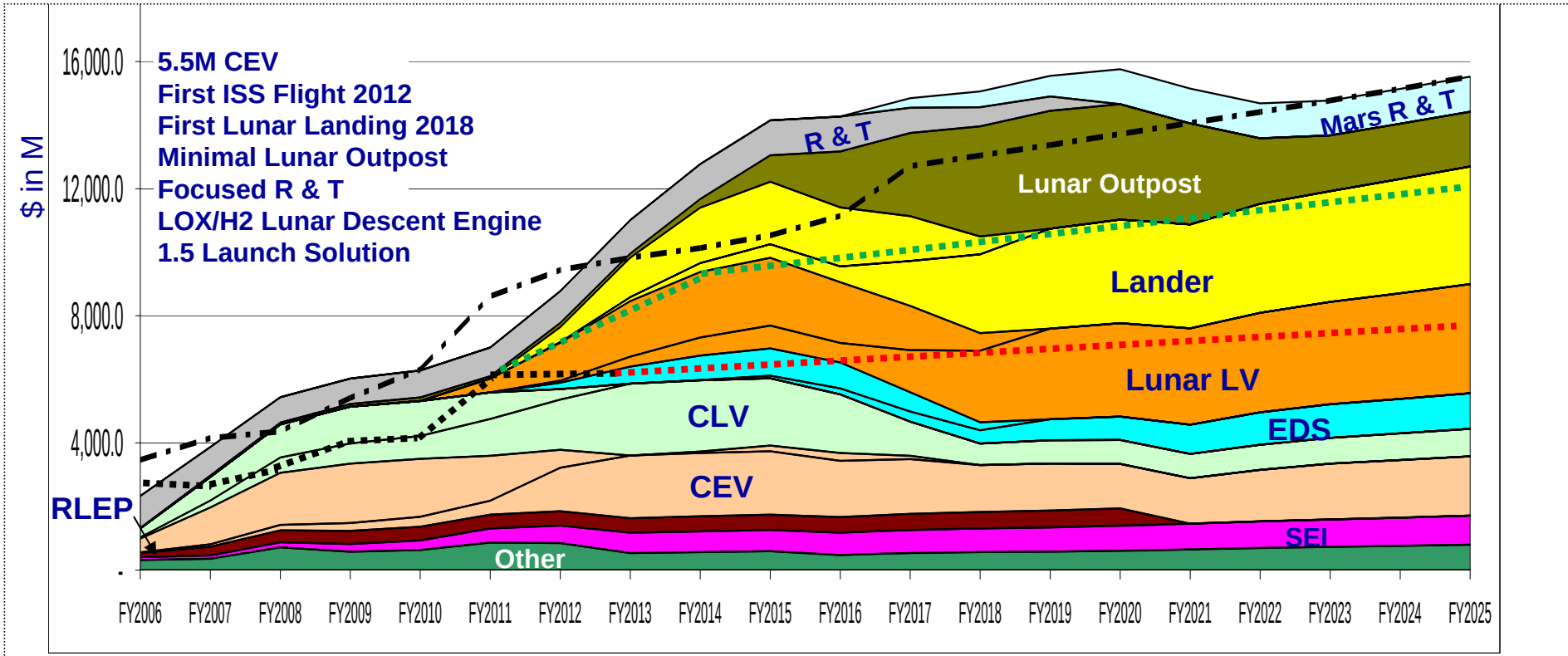
SPACE POLICY INSTITUTE

THE GEORGE WASHINGTON UNIVERSITY
THE ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS

Assessing the Options of the Augustine Committee for Human Spaceflight: An ESAS Perspective

Dr. Douglas Stanley
GA Tech / National Institute of Aerospace
September 28, 2009

ESAS Recommendation
4 Seg SRB SSME US/ 5 Seg Inline Heavy (EOR-LOR)



- 2005 Planned ESMD Budget Used During ESAS
- Actual and Planned ESMD Budget Based on FY10 President's Budget
- Projected ESMD Budget Post-2013 based on 1.4% Inflation Increase (Augustine Baseline)
- Augustine Proposed Augmentation ($3B More per Year, 2.4% Inflation Increase)

What if ESAS Requirements Were Different?

- If the CEV had not been required to go to ISS, a SDV two-launch lunar solution would have been selected
  - Two identical vehicles reduce annual operating costs, only have fixed cost on a single configuration and spread them over more launches
  - SDVs provide least expensive and safest heavy-lift capability
  - But not cost-effective or timely solution for servicing ISS
- If the architecture was focused solely on ISS servicing a EELV-based architecture (Delta-IV) would likely have been selected
  - Decreased CEV mass would allow use of existing upper stage
  - Lower cost and risk to IOC than ESAS baseline
  - Worse LOC/LOM than ESAS baseline, but still sufficient
  - Slightly quicker schedule IOC than ESAS baseline
  - But not cost-effective path to lunar heavy-lift
- Mixed-fleet approaches considered but require “keep alive” costs for Shuttle components and infrastructure
  - For Example, use of SRBs on EELV-derived core requires keeping SRB production and processing capabilities in place or many years if EELV-based CLV used
- Baseline SDV ESAS architecture provided feasible near-optimum compromise solution to meet all requirements/missions

Augustine Commission Options

	Budget	Shuttle Life	ISS Life	Heavy Launch	Crew to LEO
Constrained Options					
Option 1: Program of Record (constained)	FY10 Budget	2011	2015	Ares V	Ares I + Orion
Option 2: ISS + Lunar (constrained)	FY10 Budget	2011	2020	Ares V Lite	Commercial
Moon First Options					
Option 3: Baseline - Program of Record	Less constrained	2011	2015	Ares V	Ares I + Orion
Option 4A: Moon First - Ares Lite	Less constrained	2011	2020	Ares V Lite	Commercial
Option 4B: Moon First - Extend Shuttle	Less constrained	2015	2020	Directly Shuttle Derived + refueling	Commercial
Flexible Path Options					
Option 5A: Flexible Path - Ares Lite	Less constrained	2011	2020	Ares V Lite	Commercial
Option 5B:Flexible Path - EELV Heritage	Less constrained	2011	2020	75mt EELV + refueling	Commercial
Option 5C: Flexible Path - Shuttle Derived	Less constrained	2011	2020	Directly Shuttle Derived + refueling	Commercial

Note: Program-of-Record-derived options (Options 1 and 3) do not contain a technology program; all others do.

What Should Happen Next?

- White House should immediately decide on:
  - ISS extension through 2020,
  - Shuttle extension into 2011 and/or beyond 2011,
  - Beyond-LEO human mission destination(s) and time-frame,
  - Out-year available budget, and
  - General policy towards commercial and international ISS crew transport.
- NASA should be allowed to then define design reference mission(s) and requirements and perform ESAS-like architecture study to:
  - Perform apples-to-apples cost/safety/risk comparison of Augustine-defined options and selected other combinations of options
  - Re-visit EELV/SDV trades – including side-mount,
  - Perform detailed definition and economic analysis of propellant depots,
  - Determine true cost/risk of “commercial” crew transport,
  - Examine workforce impacts of options, and
  - Define more detailed budgets to support 2011 budget cycle.

Back-up

What About Propellant Depots?

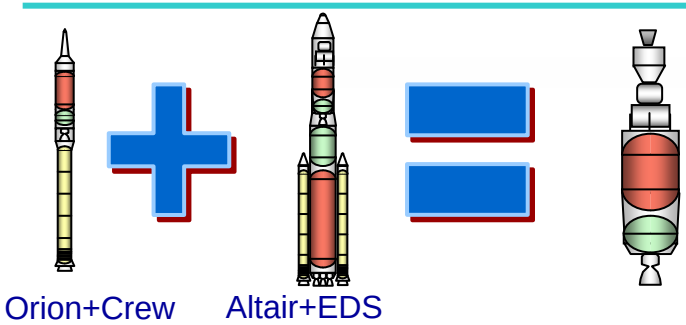
- **Use of LEO cryogenic propellant depot could improve cost-effectiveness of ESAS Baseline**
  - EDS half empty on orbit
  - Can triple cargo capacity to lunar surface (volume limited)
    - Complete lunar campaign sooner
  - Could allow EDS to do LOI
    - Smaller high-cost lander
    - Improved architecture performance

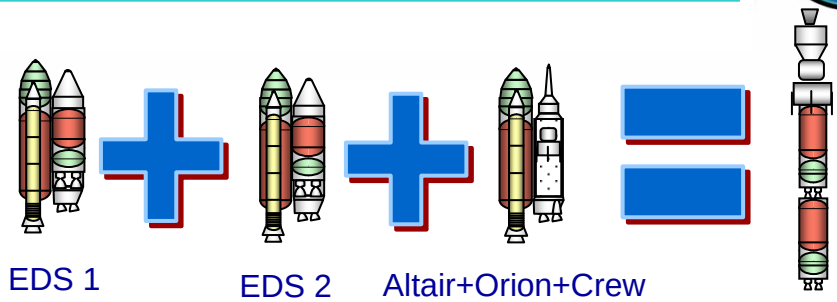
- Use of LEO cryogenic propellant depot could improve LOM of ESAS Baseline
  - Can provide continuous propellant boil-off mitigation
  - Could save multi-$B EDS/Altair in case of significant launch delay or accident
- Cost-effectiveness depends on cost of depot and propellant transfer
  - Marginal cost of Ares V launch very low (cheaper delivery system than Falcon)
  - Recent studies show using either one could save several $B
- Enables “arms length” commercial involvement/market
- Recommended for examination by ESAS, but little work done by NASA

Daniel Guggenheim
School of
Aerospace Engineering
Georgia Institute
Of Technology

Why not Side-Mounted SDV's for ESAS?

NATIONAL
INSTITUTE OF
AEROSPACE

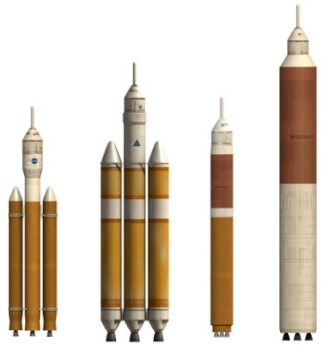




- Lower DDT&E costs and risk if Shuttle ET is used, but this limits payload capability
- Equivalent side-mount configurations tend to have 10mT less payload
- Over-powered for ISS servicing, not as cost-effective as medium-lift
- For current lunar requirements at least 3 launches required
- Increase in LOM due to more launches, stages, and on-orbit mating
- Two pad constraint implies weeks between first and last launch
  - On-orbit cryogenic propellant storage technology required to prevent boil-off
- Automated rendezvous, docking, and mating required
- Crew escape problematic due to ET proximity
  - Shock interactions from ET and proximity to potential fire or explosion

Why not EELVs for ESAS?

- Human-rated EELVs can provide cost-effective ISS servicing
  - Current lunar requirements require new upper stages
  - Similar cost and lower risk to ISS IOC than ESAS baseline
  - Worse LOC/LOM than ESAS baseline, but still sufficient
  - Similar schedule IOC than ESAS baseline
- EELVs do not provide very cost-effective growth to lunar heavy-lift capability
  - Atlas options preferred due to boost performance of RD-180s
  - ESAS baseline provides somewhat better cost, risk, LOC/LOM, and max performance, but reasonable decision makers could disagree



- Mixed-fleet approaches require “keep alive” costs for Shuttle components (e.g., SRBs) and infrastructure
- Baseline SDV ESAS architecture preferred, particularly when “tie-breakers” taken into account
  - Shuttle remediation costs
  - Cost (political and monetary) of job losses
  - Common cause failures with critical DoD system
  - Higher ammonium perchlorate costs for DoD
  - Level of DoD/NASA cost sharing of fixed costs (off-sets)

Architecture Mods Since ESAS

- In December 2005 a number of mods were made to baseline ESAS architecture without any integrated analysis to examine impact
- 5.5-meter diameter CEV changed to 5-meter
  - "Right-sized" CEV, saving cost and adding margin with little mission impact
- CEV SM propellant changed to Hypergol from LOX-Methane
  - Reduce cost and risk to IOC
  - Reduced LEO payload margin by 1,400 lb
  - Did not consider impact on LSAM ascent stage
    - Using Hypergols on ascent stage increases ascent stage gross mass by 1,650 lb, descent stage gross mass by 3,100 lb, EDS gross mass by 21,000 lb
    - Significantly decreases initial reliability of ascent stage with LOX/Methane engine due to lack of heritage experience (and increases LOC probability)
    - But would decrease DDT&E cost and risk of ascent stage if Hypergols selected
  - Cost/risk vs. performance trade where reasonable decision makers can disagree
- Baseline 4-segment w/SSME CLV changed to 5-segment w/J-2X
  - Risk and architecture life-cycle costs assumed to be reduced by cost of developing air-start SSME (several hundred $M) while providing similar payload capability
  - However, CLV IOC significantly delayed (at least a year) due to higher DDT&E costs, since the available budget drove the critical path
    - Increasing gap reduced political support and increased dependence on Russia

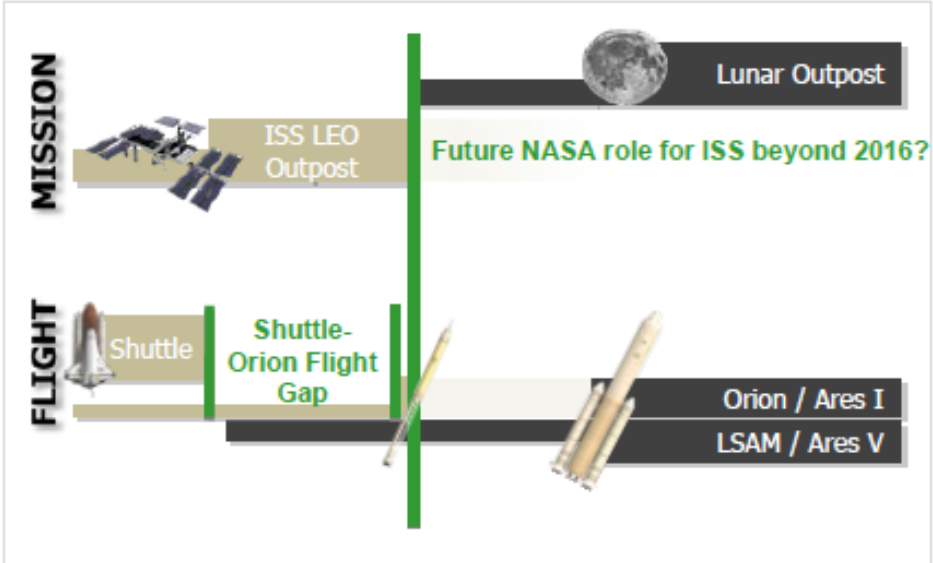
Architecture Mods Since ESAS (Cont.)

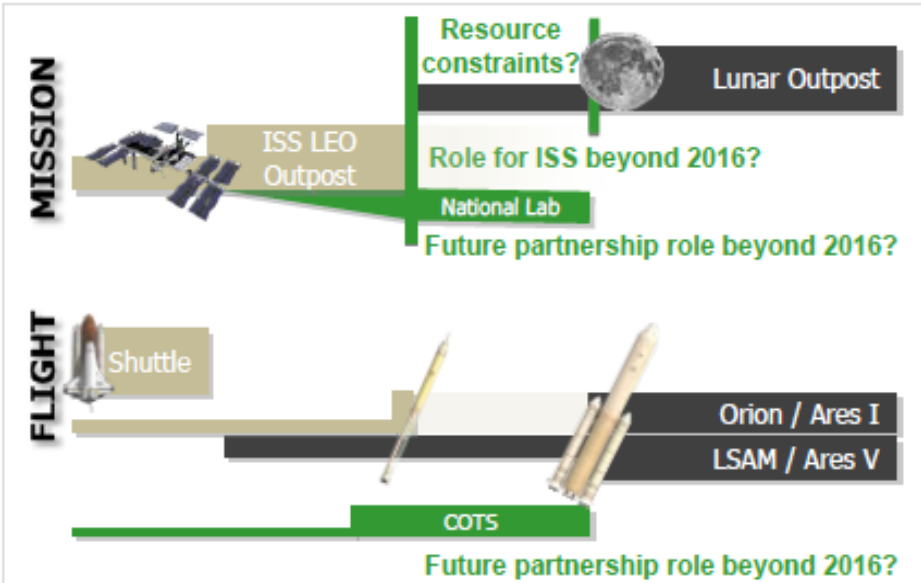
- –Subsequent reduction in J-2X Isp led to payload reduction
- –Reduced SRB longitudinal acoustic mode due to thrust oscillation from 15 Hz to 11Hz, causing interaction with first axial frequency of CLV (9 to 11 Hz)
  - This danger was specifically addressed in ESAS Appendix 6
  - Increased cost and schedule to address
  - Significantly reduced LEO payload (>1,300lb) to add systems to address
- –Increased dynamic pressure and higher acoustic loads led to added LAS mass and complexity
- –Reduced payload from J-2X and thrust oscillation problem led to change of CEV landing mode from land to water (costing >$2B in LCC)

- Elimination of SSME from CLV, led to elimination a few months later on CaLV due to prohibitive “keep alive” cost for SSME over several years
  - –Led to use of cheaper (>$30M/engine) RS-68 that had significantly lower performance (40 sec Isp)
  - –Led to increase in diameter (to 10m) and height of CaLV to maximum possible
  - –Increased gross mass by > 1Mlb for same payload
  - –Reduced propulsion cost partially offset by higher vehicle and ground infrastructure cost, likely leading to marginally lower LCC
  - –No margin left at Michoud and in VAB to grow vehicle if required
  - –Cost vs. performance/risk trade where reasonable decision makers can disagree

Near-Term and Long-Term Challenges

- **The *flight gap challenge* is coupled with the *future role of the ISS***
  - Ares I/Orion Full Operation Capability scheduled for 2016
  - NASA's and many partner nations budgets for ISS operations end in 2016
  - With current constraints, the baseline manifest currently has 1 crew rotation flight to ISS
  - Both LEO operations post 2016 and Lunar surface systems development dependent on same funds
  - Role of COTS A, B ,C , and D
  - Role of international partners
  - ISS as National Laboratory





“ASSESSING THE OPTIONS OF THE AUGUSTINE COMMITTEE FOR HUMAN SPACEFLIGHT”

September 28, 2009

SPACE POLICY INSTITUTE

THE GEORGE WASHINGTON UNIVERSITY
THE ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS

Space Exploration: Four Heresies

Paul D. Spudis

Lunar and Planetary Institute

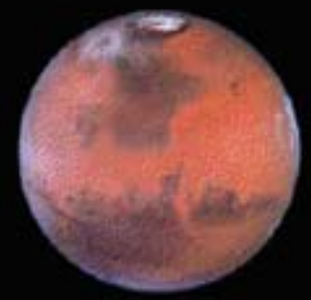
spudis@lpi.usra.edu

http://www.spudislunarresources.com
http://blogs.airspacemag.com/moon

Space Policy Institute
The George Washington University
28 September, 2009

Four Canons of the Faith

- Mars is the ultimate destination
- We need to develop a super heavy-lift (> 100 mT) launch vehicle
- We need to get the American public excited about the space program
- There's nothing wrong with NASA that more money couldn't fix



Why the Moon?

It's close

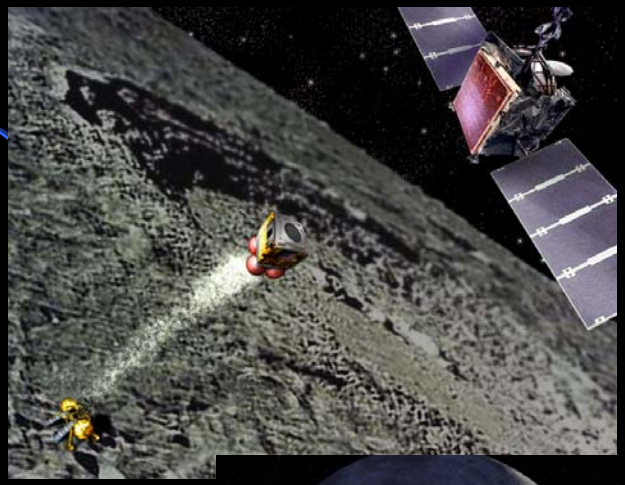
- Three days away and easily accessible (as near as GEO)
- Transport system to Moon can also access GEO, cislunar, Earth-Sun Lagrangians, and some asteroids

It's interesting

- Moon contains a record of planetary history, evolution and processes unavailable for study on Earth or elsewhere

It's useful

- Retire risk to future planetary missions by re-acquiring experience and testing with lunar missions
- Development of lunar resources has potential to be a major advancement in space logistics capability



What space faring skills do we need?

Arrive

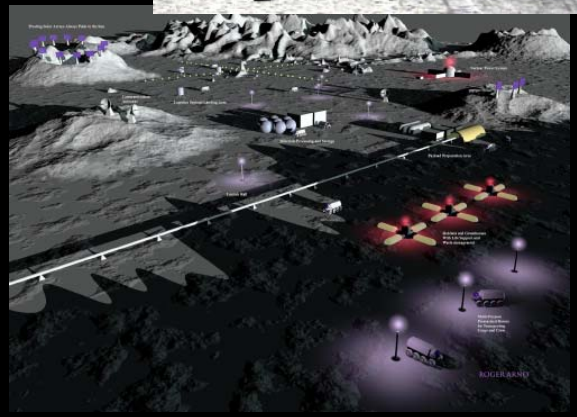
- Create transportation system to take humans to and from the Moon
- Use this system to access cislunar and translunar space

Survive

- Build habitat to safely house human explorers
- Protect from environmental hazards
- Extract consumables from local materials

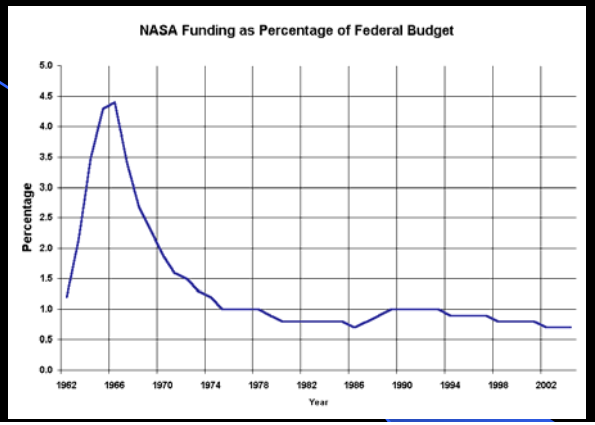
Thrive

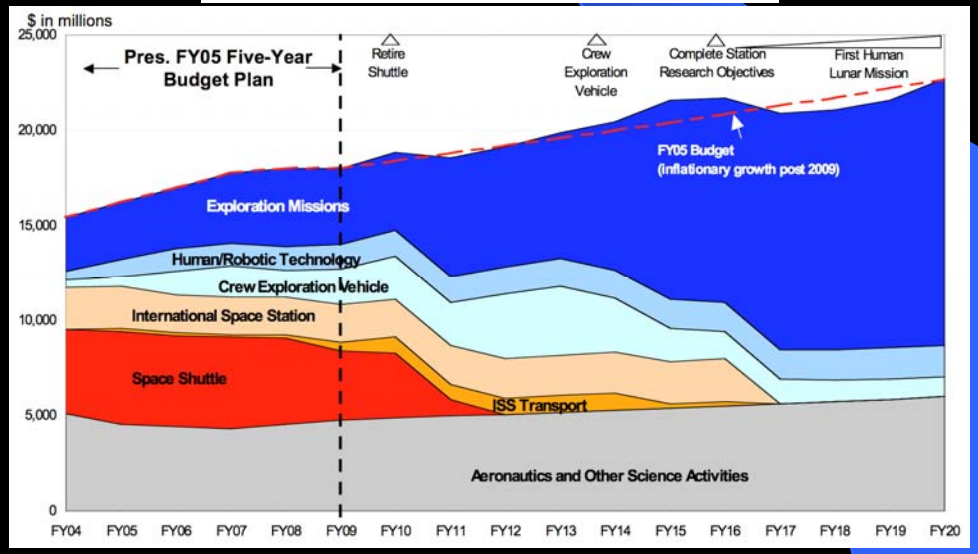
- Create new infrastructure and capabilities by using the material and energy resources of the Moon
- Extend this economic zone first to cislunar, then to translunar space



The Vision for Space Exploration:
A Fundamental Premise

- Apollo was a politically driven program; we are NOT in a similar situation
- Congress has funded NASA at (more or less) a constant level for the last 30 years (~ 1% of federal budget)
- Such spending levels appear to be politically "sustainable"
- We must be clever enough to architect a lunar return that fits this budget profile. How?
  - Small, incremental, cumulative steps
  - Learn to use what we find in space to create capability
  - Extend human reach in stages





Free variables: Apollo = funding; VSE = schedule

Public "Engagement": The Two-edged Sword

- People were split on value of Apollo
- Today, most don't know/care about space
- No one votes on basis of a candidate's opinions about space
- Live by the PR stunt, die by the PR stunt
- Polls show public is *indifferent* to space (50/50/50)
- **Apathy an asset, not a liability!**

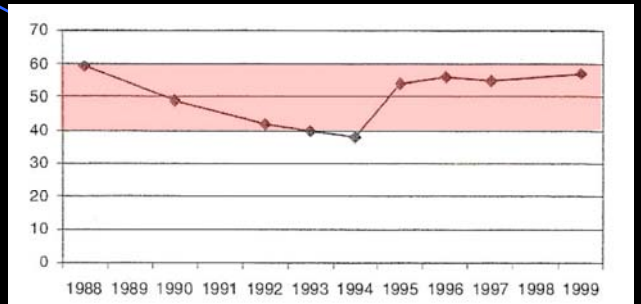


Fig. 1. Tell me how important you believe the space program is to our country.

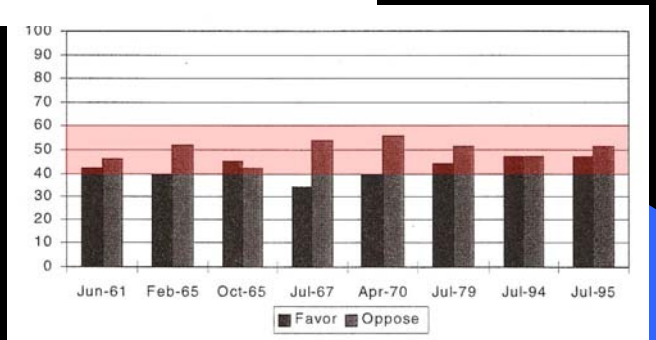


Fig. 5. Should the government fund human trips to the Moon.

R.D. Launius / Space Policy 19 (2003) 163–175

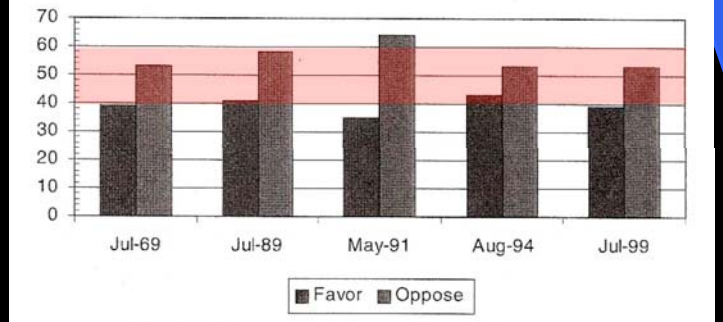
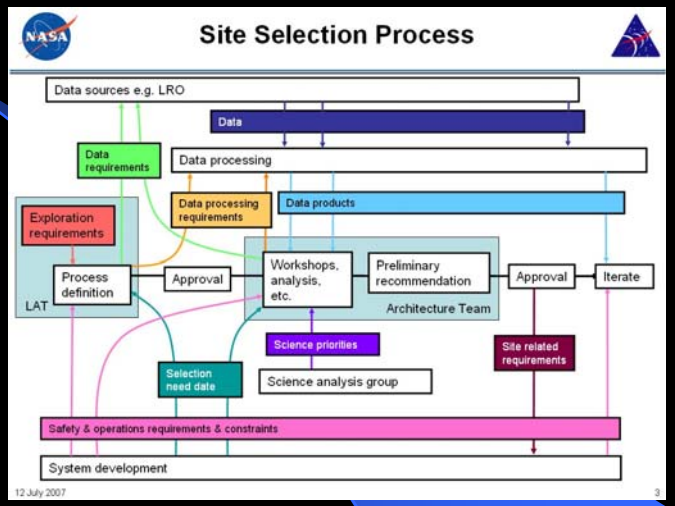


Fig. 13. Should the government fund human trips to Mars.

Differences Between Now and Apollo Era

- Sense of urgency, shared sacrifice, and national commitment (It was war!)
- Management bloat; bureaucratic and legalistic view of technical projects
- Post-Cold War deterioration of technical infrastructure and industrial base
- Blank check vs. COLA
- Societal *ennui* and risk aversion



Possible Business Models for Space

The Apollo template

- Massive government program
- Racing to somewhere
- Big infrastructure, big rockets, big budget, big PR splash
- Very high development and recurring costs; unsustainable

An alternative approach

- LV alternatives: true Shuttle-derived + commercial
- Early and continuing robotic presence
- Pace program to available resources
- Small, incremental, cumulative steps
- Build capability with time, legacy infrastructure; sustainable

Why Four Heresies?

The Four Canons are all fundamental assumptions in the Augustine Commission Report

Mars is ultimate destination

A human landing followed by an extended human presence on Mars stands prominently above all other opportunities for exploration…The Committee finds that Mars is the ultimate destination for human exploration (p. 8)

Need heavy lift rocket

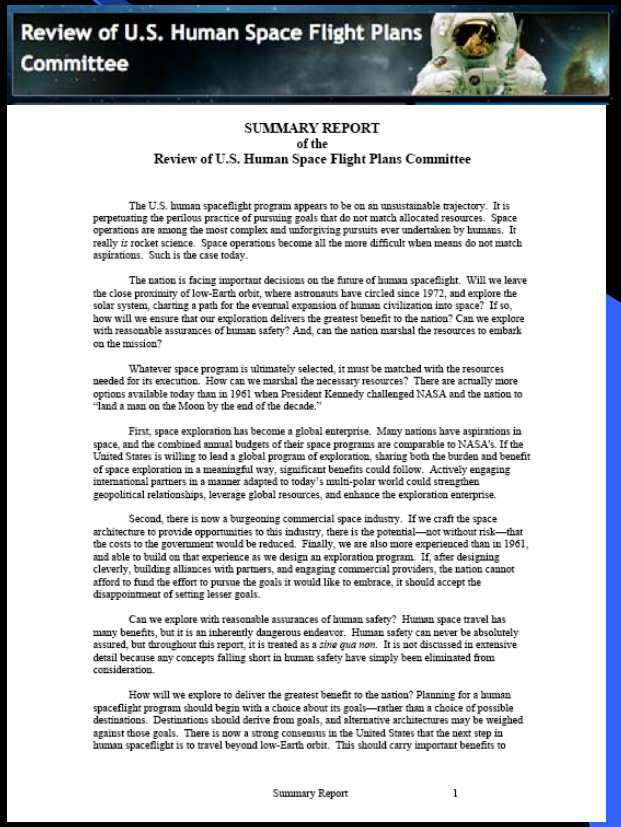
Combined with considerations of launch availability and on-orbit operations, the Committee finds that exploration will benefit from the availability of a heavy-lift vehicle. (p. 5)

Need public "engagement"

It would provide the public and other stakeholders with a series of interesting "firsts" to keep them engaged and supportive. (p. 8)

NASA just needs more money

The Committee further finds that it is possible to conduct a viable exploration program with a budget rising to about $3 billion annually above the FY 2010 budget profile. (p. 10)



SUMMARY REPORT
of the
Review of U.S. Human Space Flight Plans Committee

The U.S. human spaceflight program appears to be on an unsustainable trajectory. It is perpetuating the perilous practice of pursuing goals that do not match allocated resources. Space operations are among the most complex and unforgiving pursuits ever undertaken by humans. It really *is* rocket science. Space operations become all the more difficult when means do not match aspirations. Such is the case today.

The nation is facing important decisions on the future of human spaceflight. Will we leave the close proximity of low-Earth orbit, where astronauts have circled since 1972, and explore the solar system, charting a path for the eventual expansion of human civilization into space? If so, how will we ensure that our exploration delivers the greatest benefit to the nation? Can we explore with reasonable assurances of human safety? And, can the nation marshal the resources to embark on the mission?

Whatever space program is ultimately selected, it must be matched with the resources needed for its execution. How can we marshal the necessary resources? There are actually more options available today than in 1961 when President Kennedy challenged NASA and the nation to "land a man on the Moon by the end of the decade."

First, space exploration has become a global enterprise. Many nations have aspirations in space, and the combined annual budgets of their space programs are comparable to NASA's. If the United States is willing to lead a global program of exploration, sharing both the burden and benefit of space exploration in a meaningful way, significant benefits could follow. Actively engaging international partners in a manner adapted to today's multi-polar world could strengthen geopolitical relationships, leverage global resources, and enhance the exploration enterprise.

Second, there is now a burgeoning commercial space industry. If we craft the space architecture to provide opportunities to this industry, there is the potential—not without risk—that the costs to the government would be reduced. Finally, we are also more experienced than in 1961, and able to build on that experience as we design an exploration program. If, after designing cleverly, building alliances with partners, and engaging commercial providers, the nation cannot afford to fund the effort to pursue the goals it would like to embrace, it should accept the disappointment of setting lesser goals.

Can we explore with reasonable assurances of human safety? Human space travel has many benefits, but it is an inherently dangerous endeavor. Human safety can never be absolutely assured, but throughout this report, it is treated as a *sine qua non*. It is not discussed in extensive detail because any concepts falling short in human safety have simply been eliminated from consideration.

How will we explore to deliver the greatest benefit to the nation? Planning for a human spaceflight program should begin with a choice about its goals—rather than a choice of possible destinations. Destinations should derive from goals, and alternative architectures may be weighed against those goals. There is now a strong consensus in the United States that the next step in human spaceflight is to travel beyond low-Earth orbit. This should carry important benefits to

Summary Report 1

Back up

Architectures and Rockets

How you go beyond LEO is at least partly dependent on ***what*** you intend to do and ***where*** you intend to do it

Apollo model

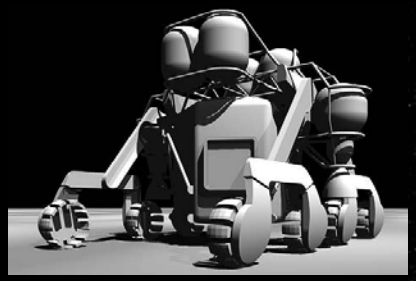
- Launch big chunks and go
- Saturn V could put 8 mT on lunar surface; enough for two crew, supplies and return vehicle
- No space assembly; everything on one vehicle
- High recurring costs; no legacy hardware

A "Transcontinental Railroad" in Cislunar Space

- Launch in smaller chunks; stage and assemble in Earth orbit
- Gives flexibility in operations, mission modes, launch vehicles
- Effort can be scaled to available resources
- Leaves space transportation legacy infrastructure

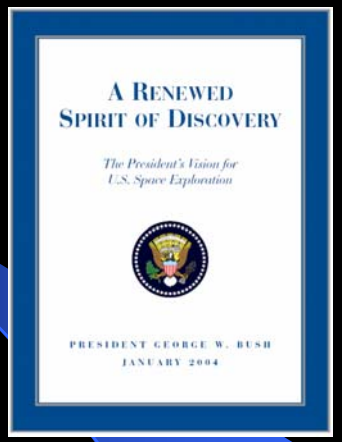
Sustainability

- CEV: Develop launch system alternatives
  - Shuttle-C, EELV, new commercial
- Create incremental robotic “presence” on the Moon
  - Orbiters, soft-landers, rovers to survey and prospect
  - Engineering tech demos for ISRU, habitat placement, site preparation
  - Infrastructure emplacement: landing pads, roads, hab sites, power and thermal control systems
- Use private sector to augment capabilities for both of above
  - Per Aldridge Commission recommendations; greatly expand data purchase, LEO access contracts, prizes
  - Need to re-build aerospace industrial base



The Vision for Space Exploration

- Conceived in response to loss of Columbia Space Shuttle, Feb. 1 2003
- Vision is designed to serve national scientific, security, and economic interests
- Five steps:
  - Return Shuttle to flight
  - Complete ISS assembly and retire Shuttle
  - Build new human spacecraft (CEV) for transport beyond LEO
  - Return to the Moon with people and robots to explore and prepare for voyages beyond
  - Human missions to Mars and other destinations
- Proposed by President Bush, endorsed by 109th and 110th Congress
  - VSE is now U.S. national policy



A Renewed Spirit of Discovery

The President's Vision for U.S. Space Exploration

President George W. Bush

January 2004

Today I announce a new plan to explore space and extend a human presence across our solar system. We will begin the effort quickly, using existing programs and personnel. We'll make steady progress – one mission, one voyage, one landing at a time.

President George W. Bush - January 14, 2004

S. 1281

One Hundred Ninth Congress of the United States of America

AT THE FIRST SESSION

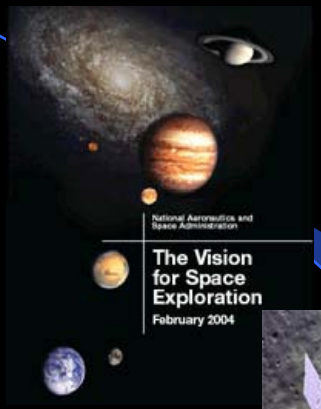
Begun and held at the City of Washington on Tuesday, the fourth day of January, two thousand and five

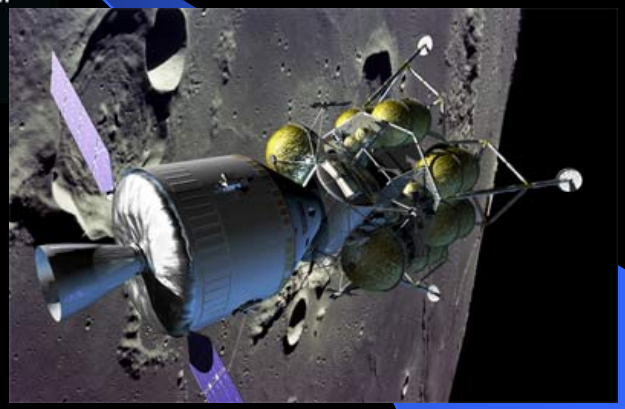
An Act

To authorize the programs of the National Aeronautics and Space Administration.

The Vision: What's It All About?

- A journey, not a race
- Small, incremental, cumulative steps
- Sustainable and affordable
- No turning back
- Build-up space-faring infrastructure
- Robotic precursors lead the way
- Expanding sphere of human "reach"
- Human-robotic partnership and synergy
- Can humans thrive off-planet?



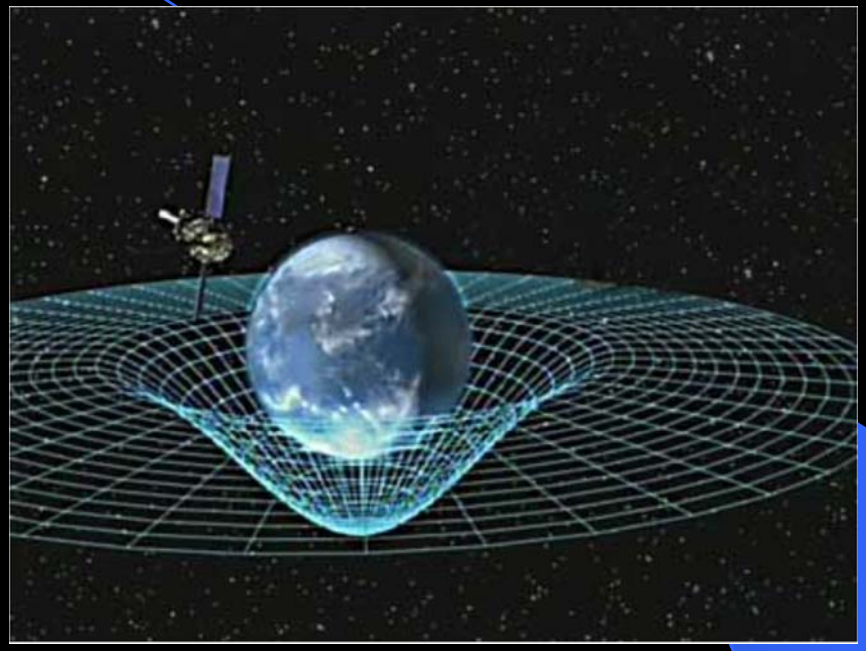


The Problem

Our ultimate goal in space is to go anywhere, anytime with as much capability as we need

We are mass- and power-limited with our spacecraft and thus, capability-limited

We will remain so as long as we are restricted to what we can lift out of Earth's gravity well



To extend our reach and capability, we must learn to use what we find in space to create new spacefaring capabilities

Space faring: Changing the Rules

Current template

- Custom-built, self-contained, mission-specific spacecraft
- Launch on expendable vehicles
- Operate for set lifetime
- Abandon after use
- Repeat

Desired template

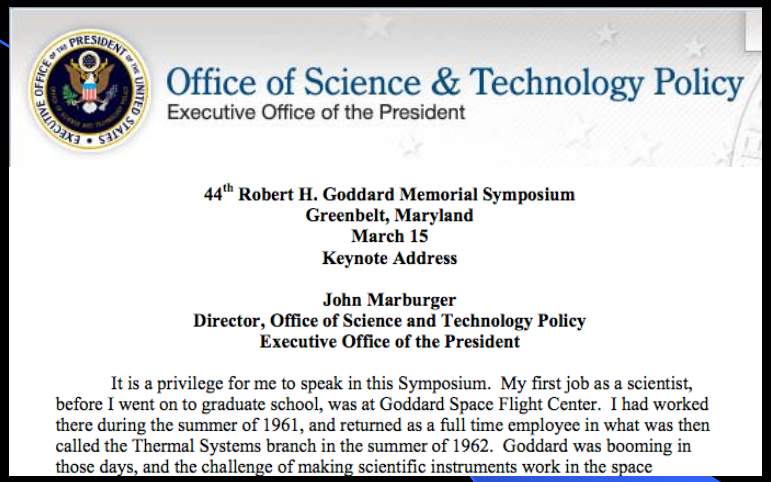
- Incremental, extensible building blocks
- Extract material and energy resources *of* space to use *in* space
- Launch only what cannot be fabricated or built in space
- Build and operate flexible, modular, extensible in-space systems
- Maintain, expand and use indefinitely

An Overlooked Key Policy Document

Speech by OSTP Director and President's Science Advisor John Marburger at Goddard Symposium, March 15, 2006

Critical Points:

- Incorporate Solar System into our economic sphere
- Ultimate goal is *to use* space for benefit of mankind
- Moon is of unique significance -- closest and most accessible source of materials and energy out of Earth's gravity well
- Development of off-planet resources makes entire Solar System accessible
- Critical architectural consideration: Space exploration budget must grow at low level to be sustainable



Office of Science & Technology Policy
Executive Office of the President

44th Robert H. Goddard Memorial Symposium
Greenbelt, Maryland
March 15
Keynote Address

John Marburger
Director, Office of Science and Technology Policy
Executive Office of the President

It is a privilege for me to speak in this Symposium. My first job as a scientist, before I went on to graduate school, was at Goddard Space Flight Center. I had worked there during the summer of 1961, and returned as a full time employee in what was then called the Thermal Systems branch in the summer of 1962. Goddard was booming in those days, and the challenge of making scientific instruments work in the space

http://www.spaceref.com/news/viewsr.html?pid=19999

What is the lunar “mission” of the VSE?

Common themes from VSE policy documents:

- Sustainable and affordable program
- Explore with robots *and* humans
- Test bed for systems and procedures on the Moon
- Learn resource utilization on the Moon
- Create new space flight capability

We are going to the Moon to learn the skills we need to live and work productively on another world

“ASSESSING THE OPTIONS OF THE AUGUSTINE COMMITTEE FOR HUMAN SPACEFLIGHT”

September 28, 2009

SPACE POLICY INSTITUTE

THE GEORGE WASHINGTON UNIVERSITY
THE ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS

MAKING THE SPACE STATION INTERNATIONAL

- January 25, 1984 – Ronald Reagan in his States of the Union address says that he had approved a NASA space station and that "NASA will invite other countries to participate so we can strengthen peace, build prosperity, and expand freedom for all who share our goals."
- Reagan repeated his invitation at June 1984 G-7 Summit in London
- Bill Clinton suggested to Boris Yeltsin at April 1993 summit in Vancouver that Russia might want to join the space station project.

Secretary of State Hillary Clinton, July 16, 2009

“Our approach to foreign policy must reflect the world as it is, not as it used to be. It does not make sense to adapt a 19th-century concert of powers or a 20th-century balance-of-power strategy. We cannot go back to Cold War containment or to unilateralism. . . . We will lead by inducing greater cooperation among a greater number of actors and reducing competition, tilting the balance away from a multi-polar world and toward a multi-partner world."

“ASSESSING THE OPTIONS OF THE AUGUSTINE COMMITTEE FOR HUMAN SPACEFLIGHT”

September 28, 2009

SPACE POLICY INSTITUTE

THE GEORGE WASHINGTON UNIVERSITY
THE ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS

Assessing the Options of the Augustine Committee for Human Spaceflight

Panel 2: Science & International Relations

A personal View from Europe

Dr. Alain Dupas

Director of Strategic Studies

adupas@club-internet.fr

Space Policy Institute,
Washington D.C., 28 September, 2009

Is the Commitment to VSE still real?

- Verbatim:
  - «*The nation is facing important decisions on the future of human spaceflight. Will we leave the close proximity of low-Earth orbit, where astronauts have circled since 1972, and explore the solar system, charting a path for the eventual expansion of human civilization into space?*»
  - «*Whatever space program is ultimately selected*»
- Comments:
  - European space agencies have lived under the impression that a firm decision had been taken in 2004 and that U.S. exploration plans were for real, even if delays might occur as always
  - A rapid clarification is needed in order to understand what we are talking about in the GES (Global Exploration Strategy) discussions

The good News: ISS Extension to 2020 supported and ISS considered a Model

- Verbatim:
  - *«The Committee finds that the return on investment of ISS to both the United States and the international partners would be significantly enhanced by an extension of ISS life to 2020»*
  - *«The strong and tested working relationship among international partners is perhaps the most important outcome of the ISS program. The partnership expresses style adapted to today's multi-polar world. That leadership could extend to exploration, as the ISS partners could engage at an early stage if aspects of exploration beyond low-Earth orbit were included in the goals of the partnership agreement.»*
- Comments:
  - All partners are expecting this extension but it may be useful to look even further (evolution towards a commercial facility? A transportation and support node for exploration projects?)
  - The ISS cooperation model worked finally very well and could be the "reference model" for the future

An Optimistic View of International Partners' Commitment to Human Exploration

- Verbatim:
  - *«[…] space exploration has become a global enterprise. Many nations have aspirations in space, and the combined annual budgets of their space programs are comparable to NASA's. If the United States is willing to lead a global program of exploration, sharing both the burden and benefit of space exploration in a meaningful way, significant benefits could follow. Actively engaging international partners in a manner adapted to today's multi-polar world could strengthen geopolitical relationships, leverage global resources, and enhance the exploration enterprise.»*
- Comments:
  - Efforts for human spaceflight by most ISS partners (except Russia) are much smaller than NASA's. It may be different for China and perhaps India. Aspirations for human deepspace exploration are not shared.
  - **Only a call for cooperation at the highest (national) political level** could lead to a positive answer in Europe, Japan and Russia
  - The G-20 group could provide a suitable forum to attract China, India, Brazil, South Korea

Collège de Polytechnique®

Additional Comments

- The most pressing issue is servicing ISS after Shuttle's retirement.
  - ATV is the only hardware ready in Europe
  - A cargo return capability is not planned before 2017
  - A human LEO access vehicle is not contemplated before 2025
- Could Europe accelerate these programs? Yes but the political will is not there.
- For human exploration:
  - participation in a program aiming for lunar landing by 2020 was totally out of question for political, financial and technical reasons
  - Later goals would be much more comfortable for Europe and would leave time to discuss and plan coordinated strategies and programs
  - Option 4 (« Moon First ») and 5 (« Flexible Path ») would offer interesting opportunities for Europe. Option 4 would increase the confidence in the continuity of the U.S. policy

A very positive conclusion

- **Verbatim :**
  - ***«International partnerships: The U.S. can lead a bold new international effort in the human exploration of space. If international partners are actively engaged, including on the "critical path" to success, there could be substantial benefits to foreign relations, and more resources overall could become available».***
- **Comments:**
- Good to read this sentence, particularly about the «critical path»
- So let's (try to) do it…

“ASSESSING THE OPTIONS OF THE AUGUSTINE COMMITTEE FOR HUMAN SPACEFLIGHT”

September 28, 2009

SPACE POLICY INSTITUTE

THE GEORGE WASHINGTON UNIVERSITY
THE ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS

Assessing the Options:
the Augustine Committee Review of U.S. Human Space Flight Plans

September 28, 2009

The George Washington University
Space Policy Institute

Bretton Alexander
President, Commercial Spaceflight Federation

COMMERCIAL SPACEFLIGHT FEDERATION

The "Original" Vision for Space Exploration

- **U.S. Space Exploration Policy (NSPD-31), Jan. 14, 2004**
  - "**Develop** a new crew exploration vehicle [Orion] to provide crew transportation for missions **beyond low Earth orbit**
  - "**Acquire** crew transportation **to and from the International Space Station**, as required, after the Space Shuttle is retired from service
  - "**Pursue commercial opportunities** for providing transportation and other services supporting the International Space Station and exploration missions beyond low Earth orbit"

- **President's Commission on Implementation of U.S Space Exploration Policy (the "Aldridge Commission"), 2004**
  - "The Commission recommends NASA recognize and implement a far larger presence of private industry in space operations... **most immediately in accessing low-Earth orbit [LEO]**"
  - "The Commission believes that NASA should **procure all of its low-Earth orbit launch services** competitively on the commercial market"

Government *beyond LEO*
Commercial *to LEO*

COMMERCIAL SPACEFLIGHT FEDERATION

A Natural Evolution

- **Commercial launch industry has a proven record of success:**
  - Trusted to fly multi-billion dollar national security missions
  - ULA has flown 69 successful Delta II, Delta IV, and Atlas V missions since 2002
  - Orbital has flown 11 successful Pegasus and Taurus flights since 2002, and Taurus II is under development
  - SpaceX has flown 2 successful Falcon flights since '02, with Falcon 9 heading to the Cape shortly
  - NASA signed contracts for $3.5 billion in cargo services to ISS

Committee's endorsement of commercial human spaceflight is a natural evolution, not a dramatic leap

COMMERCIAL SPACEFLIGHT FEDERATION

Safety is Paramount

- **NASA will be there every step of the way**
  - Design must meet NASA human rating requirements (8705.2B)
  - NASA will play a role in design, development, and operations
- **Human spaceflight is almost 50 years old**
  - Technical requirements are well understood and U.S. industry has been a part from Day One
- **"Human-rating" of ELVs is a non-issue**
  - Mike Griffin, in testimony to Congress in 2003: "What, precisely, are the precautions that we would take to safeguard a human crew that we would deliberately omit when launching, say, a billion-dollar Mars Exploration Rover (MER) mission? **The answer is, of course, 'none'.** "
- **Rendezvous and prox ops done by U.S., Russia, Europe, and Japan**
- **Astronauts on commercial flights will not fly on unproven vehicles**
  - Atlas has a demonstrated track record
  - Falcon 9 and Taurus II will have conducted cargo flights to ISS
- **Veteran NASA astronauts work at commercial space companies**

NASA will be there every step of the way

COMMERCIAL SPACEFLIGHT FEDERATION

Ares I or Commercial? – *A False Choice*

- **"The Committee found that, because of technical issues and budget cuts, the Ares I schedule no longer supports the ISS"**
  - Critically, the Committee determined that even with an extra $3 billion, NASA could not afford both Ares I and ISS life extension to 2020
  - All of Augustine's Integrated Program Options that included Ares 1 did not include ISS life extension to 2020, enhanced R&D, and enhanced ISS utilization
- **Also, Commercial Crew / ISS is a separate issue from the debates about exploration architectures beyond Earth orbit**
  - As Mike Griffin has pointed out, the CEV [Orion] capsule intended for exploration beyond low Earth orbit and is not optimized for ISS servicing
- **NASA needs commercial crew to extend ISS**
  - Current plan is to outsource to Russia at $51m per seat

Augustine's Real Choice: Ares I *or* ISS

COMMERCIAL SPACEFLIGHT FEDERATION

“ASSESSING THE OPTIONS OF THE AUGUSTINE COMMITTEE FOR HUMAN SPACEFLIGHT”

September 28, 2009

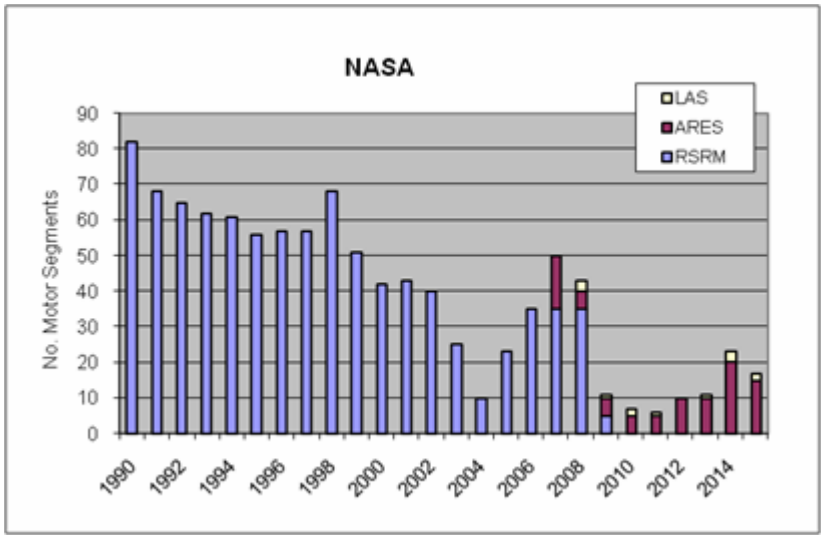
SPACE POLICY INSTITUTE

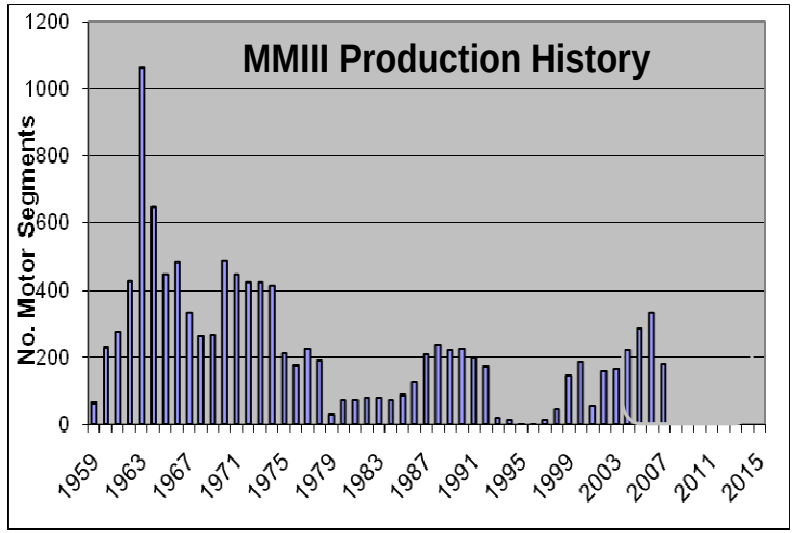
THE GEORGE WASHINGTON UNIVERSITY
THE ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS

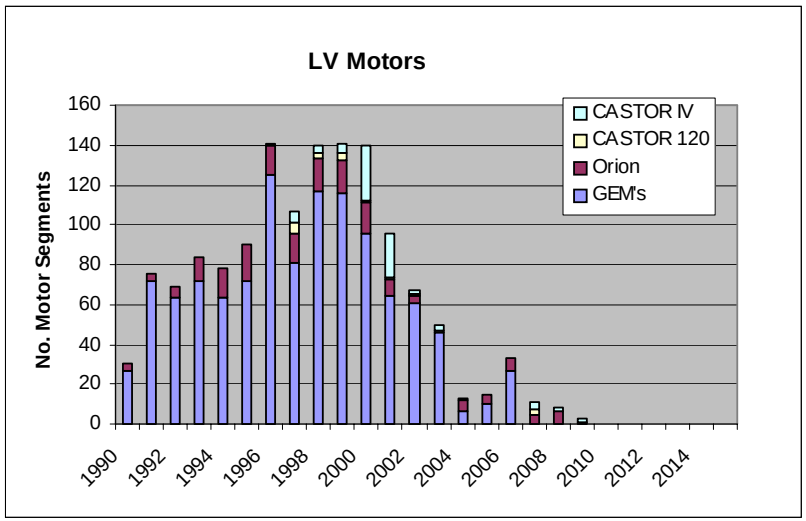
Solid Rocket Motor (SRM) Sector Industrial Overview

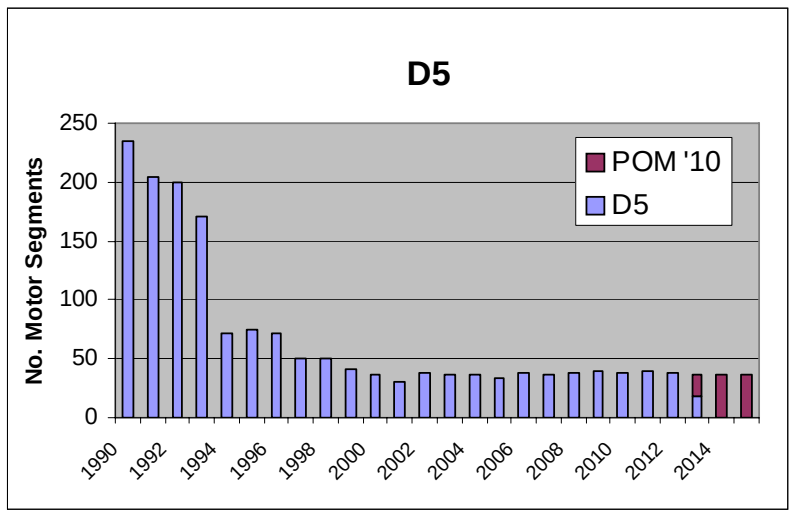
Robert M. Read
OUSD(AT&L)/Industrial Policy
Robert.Read@osd.mil
September 28, 2009
(703) 602-4287

Large SRM Production Decline



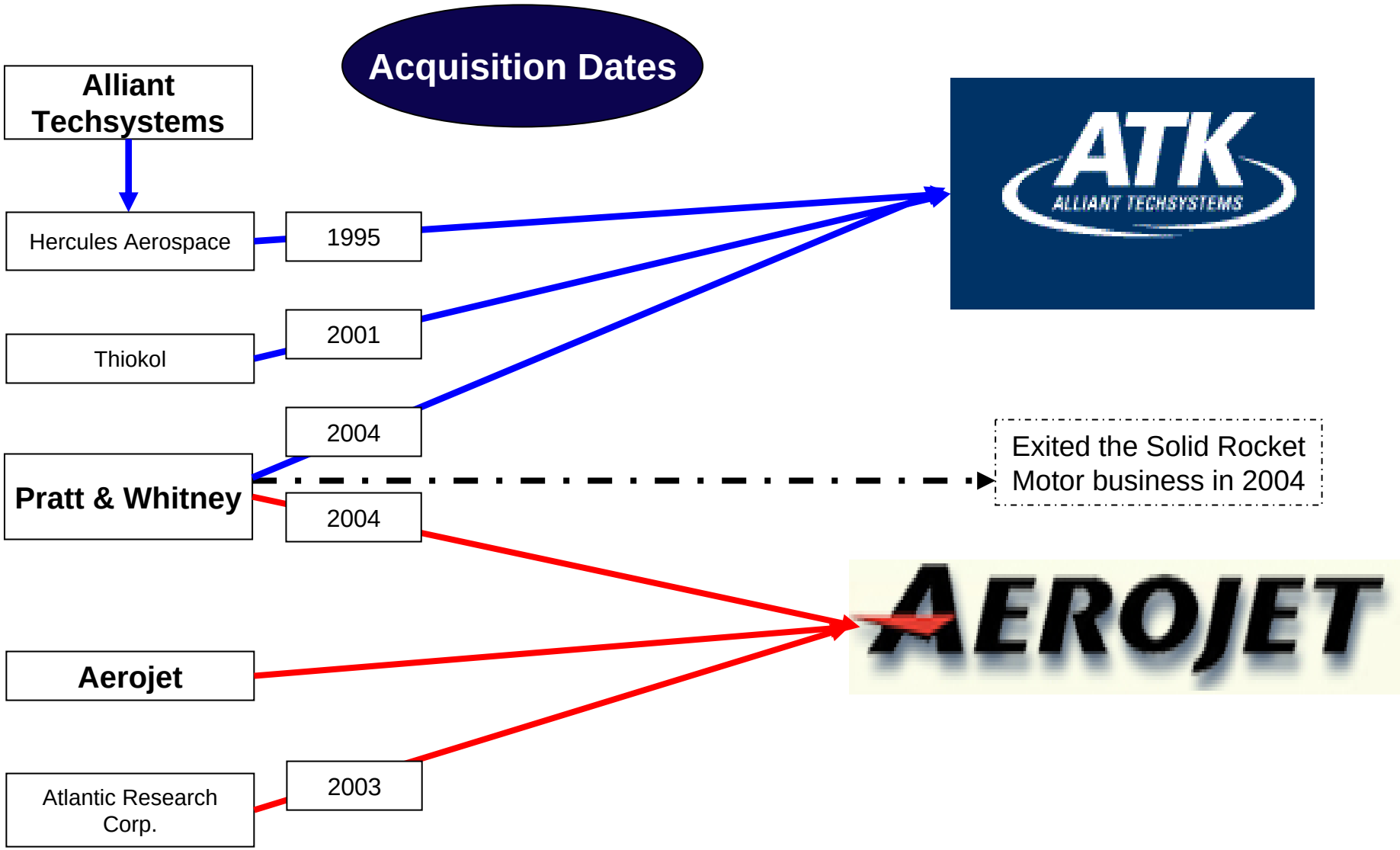






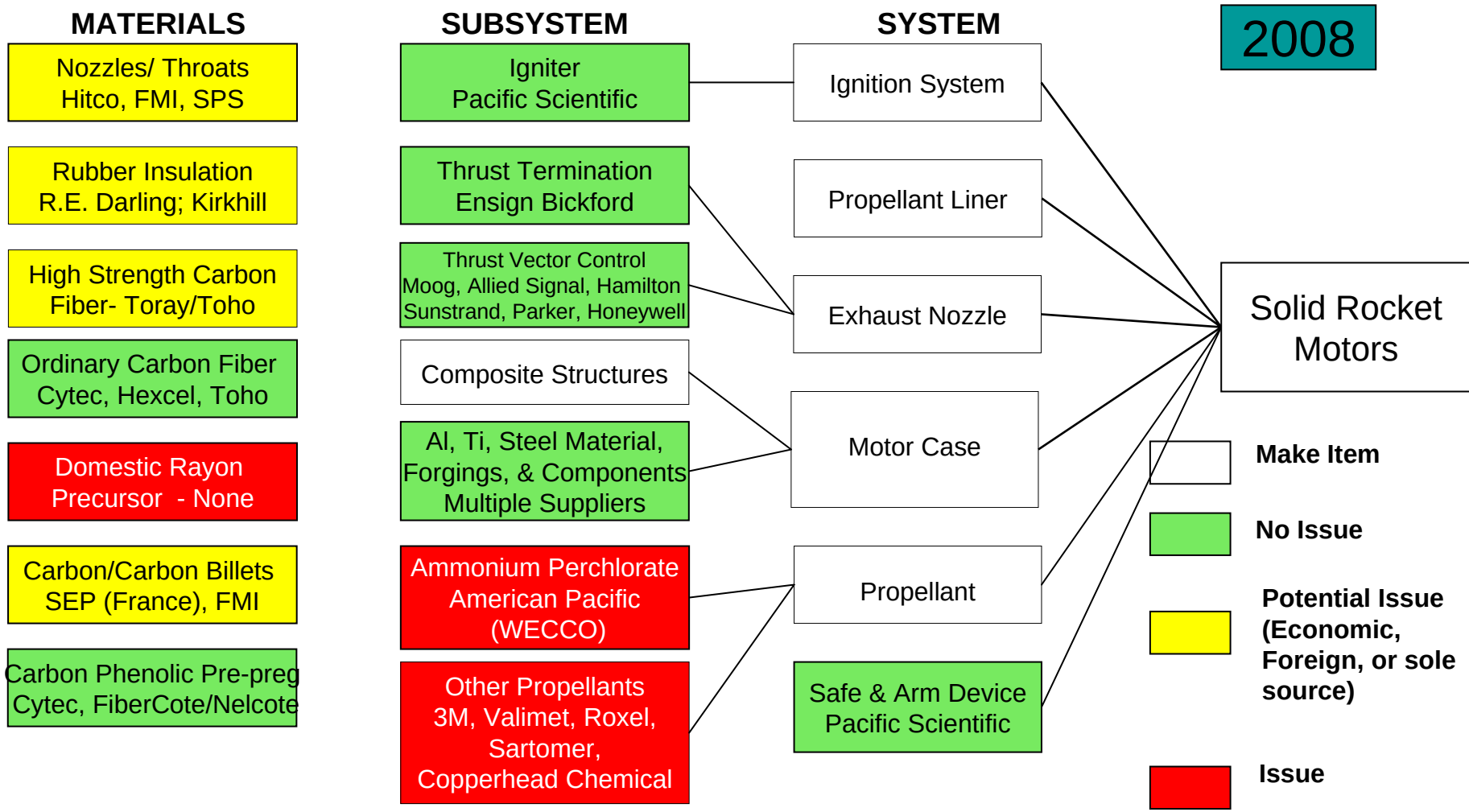
Source: ATK

Consolidation in the SRM and Related Industries



Source: BAH Derived

Large System Sub-tier Suppliers & Niche Providers – ATK and Aerojet Assessment



Source: Producer provided information, BAH analysis and derivation

Activities Impacting Solid Rocket Motor Industrial Sector

- DoD program decisions
- Nuclear Posture Review and Ballistic Missile Defense Review
- NASA path forward; results from Augustine Commission

“ASSESSING THE OPTIONS OF THE AUGUSTINE COMMITTEE FOR HUMAN SPACEFLIGHT”

September 28, 2009

SPACE POLICY INSTITUTE

THE GEORGE WASHINGTON UNIVERSITY
THE ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS