Space Transportation Architecture Study (STAS)

Executive Summary

The Basic Question and the Boeing Approach to the Answer

What is the best investment plan and policy structure for the government to continue America's leadership in human space flight leadership in human space flight?

Key Near-Term Decisions. The U.S. government faces near-term decisions concerning the future of the Space Shuttle that will have significant long-term impact on space transportation. At the same time, the aerospace industry is facing similar, parallel decisions regarding future launch vehicle business. Intuitively, it makes sense to maximize the synergy between commercial launch services capabilities and the government's human space flight program, aiming towards establishing a family of vehicles that meet both market needs. Successful synergy requires a partnership between government and industry, where industry is able to achieve market-driven returns for its investment, and the U.S. Government is able to achieve low costs for access to space. The Boeing Space Transportation Architecture Study (STAS) evaluates the market opportunities for Government and Commercial Space Launch, the available technologies, and the business proposition required for industry to commit to investment in Human Space Flight. The study concludes with a series of key findings and six specific recommendations.

Boeing STAS Investigation. In implementing STAS, Boeing addressed these critical decisions. We explored alternative approaches for the nation to satisfy its known human space flight needs through 2020. We looked both at maintaining the current Shuttle system (with incremental improvements and new management structure) and at replacing it with a new, more advanced Next-Generation Launch System (NGLS), as well as other alternatives.

Overall, we combined 269 launch systems into 14 analytical architectures and performed repeated sensitivity investigations of three recommended approaches per the STAS statement of work.

Credible Cost and Price. We pooled expertise from all Boeing locations and heritage companies. We compared Boeing cost estimates with external, independent cost estimates for principal new systems. For commercially developed systems, we grounded our launch services price estimates to solid market and competition knowledge. We generated detailed manifesting simulations to determine probable competitive market capture based on these prices and engineered system capabilities. For the crucial analysis of International Space Station (ISS) traffic, we used the ISS program traffic modeling team.

We brought to bear on STAS the same technical and business modeling tools used for strategic commercial analysis at Boeing. These tools provide a genuine, experienced commercial perspective on future space transportation investments.

It's a Business Issue. While the choice of a path for the national space flight program involves technology issues, business issues drive the decisions: investment costs versus acceptable financial returns, risk, and market receptiveness.

Boeing investigated business parameters such as internal rate of return, net present value, development cost, market capture, operations cost, and NASA investments for hardware development and technology advancement. These financial parameters were combined with key technical factors such as vehicle performance, risk, development schedule, and payload capability

1. The Market Drives Investment and Return

Industry investment in a new launch vehicle to replace Shuttle depends upon the size, growth, constancy, and commitment of the market.

Like all businesses, the space launch business begins with the market (Figure 1). Who are the customers? How big is the market? How dependable is the market? Will it grow? What is the market willing to pay? Market knowledge and competitive position analyses enable us to generate credible revenue projections and make confident investment decisions.

The NASA human space flight market for the foreseeable future is well understood: human as well as pressurized and unpressurized cargo services for ISS. Department of Defense (DOD) and NASA markets for satellite launch are also steady and predictable.

The commercial satellite launch market is much more volatile. Destination orbits vary; prices are highly competitive; costs are often subsidized; launch supply may soon exceed demand. Currently, there is no commercial demand for reusability, cargo return, or human intervention. Growth opportunities are focused on low earth orbit (LEO) and medium earth orbit (MEO), where the market is most unpredictable.

In the near future, the needs of these diverse markets will continue to be met by Shuttle and by U.S. and foreign expendable launch vehicles (ELV's). Over time, greater reusability will be introduced to replace the current systems with more cost-effective alternatives. NGLS will replace Shuttle and many ELV's in the future, offering lower priced launch services to existing markets and invigorating new market expansion. NGLS success depends not so much on technology issues as on financial issues and capturing market share. Unlike existing, "niche market" systems, NGLS must compete in all markets (NASA, DOD, commercial) to succeed.

The Boeing STAS results are based only on these real markets, and on our knowledge of potential launch services buyers. Multibillion-dollar industry investments in NGLS require a solid foundation. Bold developments require investor commitment. Investor commitments require credible, market driven business cases and corresponding customer commitments.

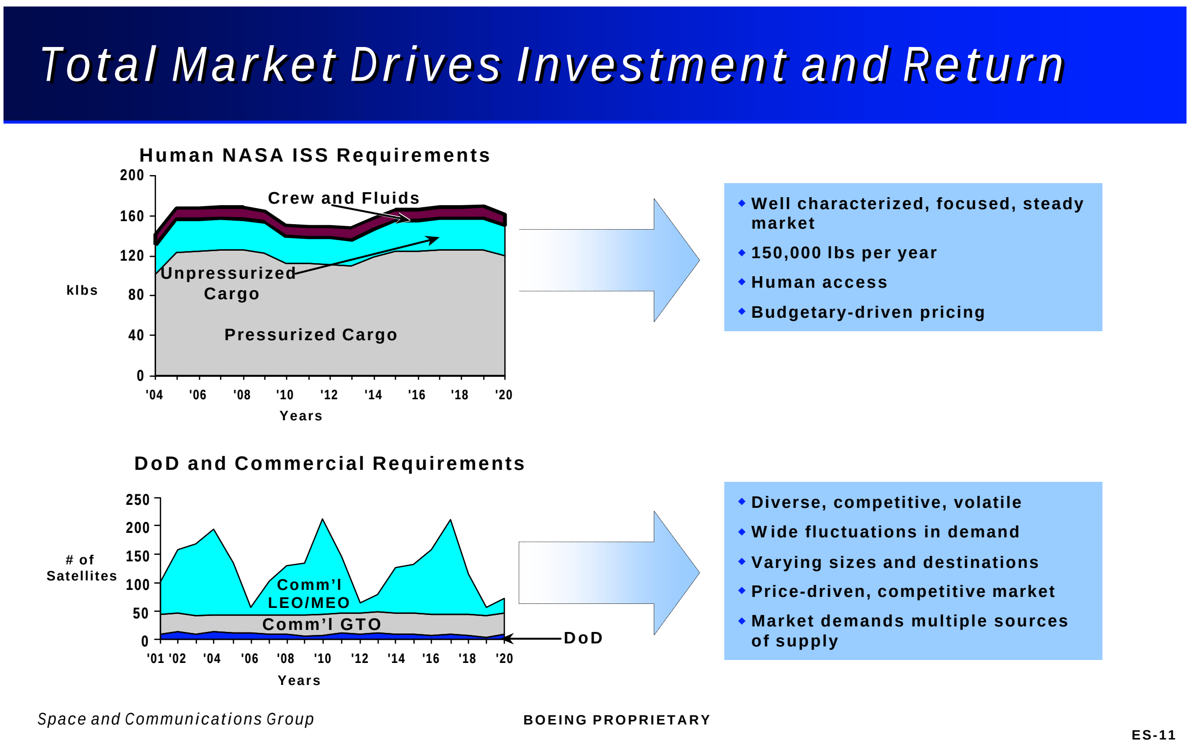

Figure 1. Total Market Drives Investment and Return

2. STAS Results – Scenario Discussion

Boeing examined all three STAS scenarios in detail, focusing on specific questions and issues.

Options Examined: In implementing STAS, Boeing explored three fundamental scenario assumptions for future space transportation:

1. Keep Space Shuttle operational until 2020.
2. Replace Space Shuttle when cost effective.
3. Assume NASA's fiscal year 1999 (FY99) budget.

Shuttle through 2020. Scenario 1 assumes Shuttle supports assembly and on-going logistics needs of the International Space Station. A number of issues were addressed including:

a) Upgrade and operating cost for the Shuttle to fly through at least the year 2020.
b) Required and potential Shuttle launch rates.
c) Innovative near-term operations cost savings, such as a United Space Alliance (USA) firm fixed price (FFP) launch services contract that incentivizes capture of commercial payloads.
d) The cost benefit of Shuttle upgrades.

In our recommended approach for Scenario 1, USA assumes responsibility--and risk--for Shuttle operations in 2004 in a government owned, contractor operated, FFP arrangement. For $1.8B annually, USA assumes responsibility for upgrades and mission-enabling hardware investment, (e.g. upper stages) performs six standard ISS and NASA missions each year, and is permitted to seek additional revenue through commercial use of Shuttle. This approach saves NASA $600M per year for routine ISS operations and effectively eliminates NASA's long-term investment in upgrades.

At the current Shuttle flight rate projections, a Reusable First Stage (RFS) investment was determined to not be justified on a cost-benefit basis. An RFS decision must be based on the non-financial value of safety and reliability improvement.

Replace Shuttle when cost effective. Scenario 2 examined replacing the Shuttle with a space transportation system that performed as well as commercial cargo missions. Such a vehicle would be owned and operated by industry. Within STAS, we investigated Shuttle replacement options with ranges of reusability and levels of staging to arrive at the most cost effective replacement option.

Among the key issues in this scenario are:

a) Cost credibility: technology maturation, vehicle acquisition, and vehicle operations.
b) Who (NASA or industry) pays for what, and when?
c) The ability of one or more NGLS to compete in the commercial market.
d) ISS servicing approach for human access and human related cargo—ISS operations impact
e) NASA budget requirements for technology advancement investment, vehicle development investment, and ISS market commitment.
f) The earliest credible date to replace Shuttle

In our recommended approach for Scenario 2, a highly re-usable Two-Stage-To-Orbit (TSTO) NGLS is brought into service in 2006 for commercial payloads. The vehicle begins cargo service to ISS in 2007, then adds human missions to ISS in 2008. After three years of decommissioning, the Shuttle budget is zeroed and NASA's recurring cost for human space flight is reduced to $1B annually.

Considering realistic market assumptions, credible market capture, and other business considerations, the Boeing STAS analysis indicates the maximum industry investment for NGLS should not exceed $4-$4.5B. Today, Boeing estimates a minimum acquisition cost of $5.7B for a low-risk TSTO NGLS. Even with a firm multi-year commitment of ISS missions, government assistance is needed to offset the investment gap. Options include government contributions in the areas of technology investment, prototype development, direct program co-investment, financial support, and a variety of industry/government partnership arrangements.

Less reusable options, such as reusable transfer vehicles similar to Crew Return Vehicle (CRV) were determined to be not cost effective using evaluation criteria specified in the STAS study. The recurring cost ($275M) coupled with the increased flight rate (11-12) required to perform the equivalent Shuttle missions resulted in a higher cost to NASA than the Shuttle.

FY99 Budget Constraint. To fit within NASA's 1999 investment profile for Scenario 3, we carefully time-phased the Scenario 2 plan. Technology and vehicle development is serial rather than parallel to reduce risk. Therefore, industry investment decisions and the NASA usage commitment is delayed until technical and market risks are mitigated. The Shuttle stops flying in 2011 and NASA's transportation budget declines to $1B per year in 2013.

3. Scenario 1

Keep Shuttle operational until 2020.

In Scenario 1 we addressed the key NASA question, can Shuttle fly to 2020 cost effectively? The answer is yes. With minimal investment in upgrades to avoid obsolescence, the Shuttle can fly beyond 2020. By pursuing a FFP contract with a commercial operator or by investing in cost reduction upgrades, NASA's annual human space flight budget can be reduced from $2.4B to $1.8B by 2020.

Figure 2 (depicting Scenario 1) shows the Shuttle continuing to operate through 2020, with upgrades performed through 2011. CRV and transfer vehicles support ISS as the space station comes on line. The evolved expendable launch vehicles (EELV's), medium and heavy systems, become operational in the early 2000's. Shuttle continues to perform ISS support and some other NASA missions. The ELV's continue to serve the commercial, DOD and NASA cargo markets.

Scenario 1 –
Shuttle Through 2020

Architecture Description

- **Shuttle with upgrades flies through 2020; $1.4B investment in cost savings upgrades 2001-2011, $25M per year investment in obsolescence avoidance**
- **CRV deployed to space station as lifeboat**
- **EELV supports other commercial and DOD mission requirements**

OMB Decisions

- **Continue to fund Shuttle upgrades**

Total savings against baseline through 2020: $6.8B (discounted)

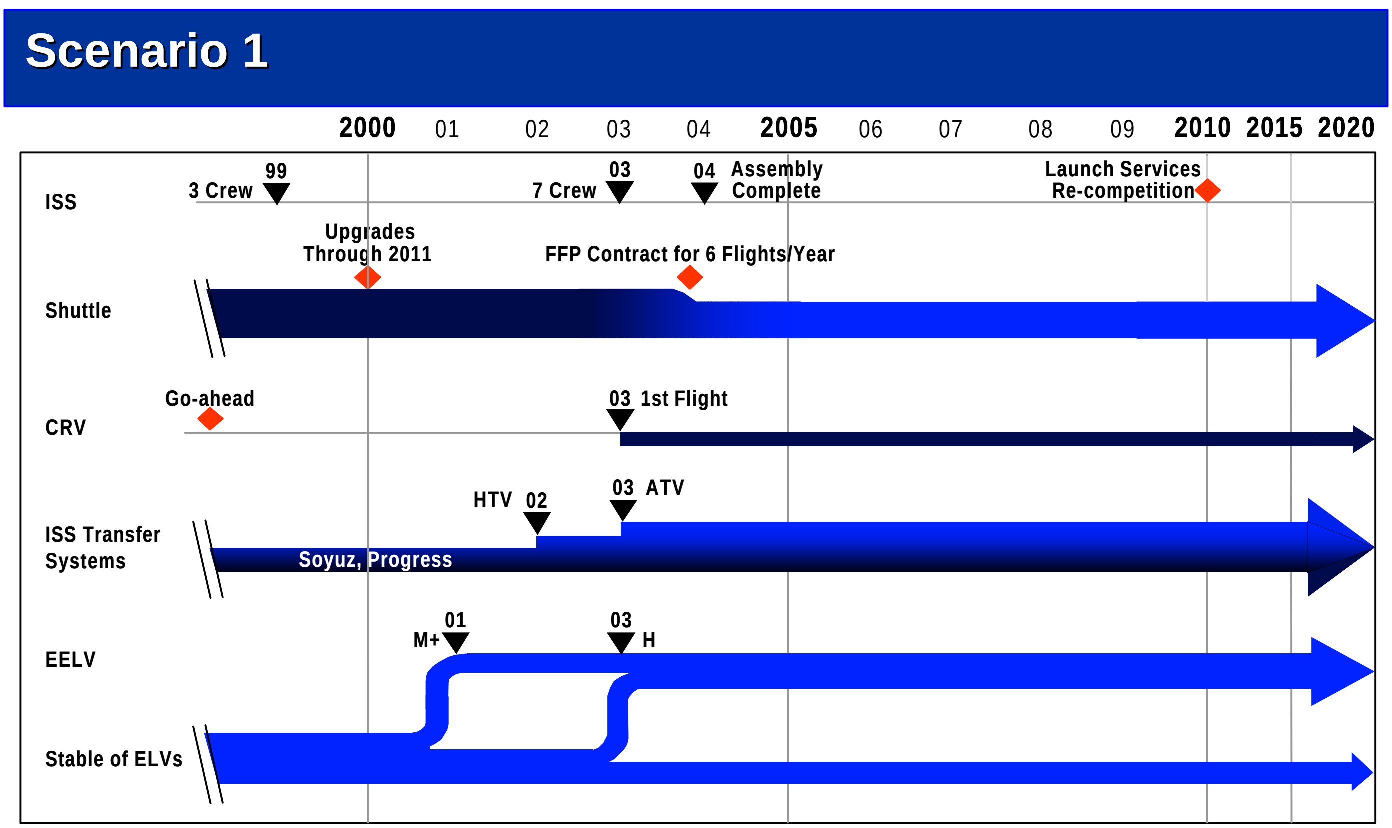

Figure 2.

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4. Scenario 2

Replace Shuttle when cost effective.

In Scenario 2 we addressed another key NASA question, how far down can a Shuttle replacement drive the cost of human space flight? The answer is a steady state cost of $1B per year for commercial human spaceflight launch services. Up-front Shuttle upgrade investment is reduced to $550M from 2001-2006. Out year savings of $1.4B annually are achieved by 2011.

Figure 3 (depicting Scenario 2) shows the TSTO NGLS entering the picture. NASA technology and hardware development funding commitments made in 2000 are assumed to close the NGLS investment gap. NGLS development proceeds at a rapid pace following a full-scale development with authorization to proceed in 2002. First commercial payloads are carried on the NGLS in 2006. NASA commitment to the NGLS is based upon a competitive NASA award in 2002 for ISS launch services to begin in 2007. In 2007 and 2008, the NGLS assumes ISS cargo and crew missions, respectively. While ELV's will continue in the market, the NGLS also begins to capture a significant portion of the DOD and commercial payload market.

Scenario 2 –
Replace Shuttle as Soon as Cost Effective

Architecture Description

- **Shuttle flies through 2007**
- **Shuttle held as backup through 2008**
- **NGLS commercial IOC in 2006**
- **NGLS flies commercial missions in 2006, ISS cargo in 2007, and assumes all ISS missions in 2008**
- **CRV deployed on Shuttle then NGLS**
- **ELV's continue to fly at reduced rates**

NASA/OMB Decisions

- **Technology risk reduction program initiated in fiscal year 2000**
- **ISS launch services award in fiscal year 2002 to allow commercial investment**

Total Cost Savings: $8.4B (discounted) against Shuttle baseline

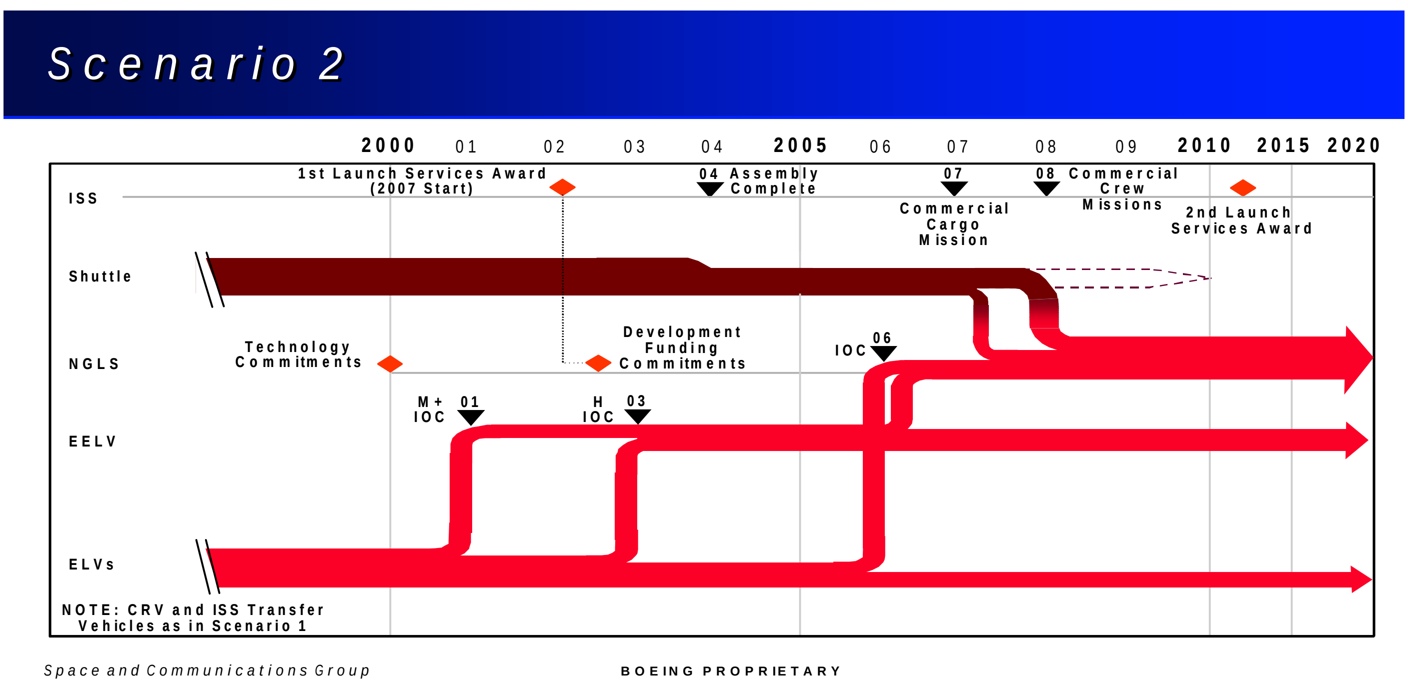

Figure 3.

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5. Scenario 3

Assume NASA's FY99 budget.

In Scenario 3 we answered the bottom line question of utmost importance to both NASA and office management budget; what is the cost of human space flight given existing NASA budget constraints? The answer is $1B per year for commercial launch services. Up-front Shuttle upgrade investment is reduced to $800M from 2001-2009. Out year savings of $1.4B annually are achieved by 2014.

Scenario 3 (Figure 4) is similar to Scenario 2, except the development of the TSTO NGLS is phased to fit within the FY99 NASA budget limitations. NASA first focuses available funds on technology risk reduction (e.g., NGLS engine technology) starting in 2000. A competitive launch services contract for ISS logistics support is awarded in 2004. The NGLS begins commercial operations in 2009, and the Shuttle is replaced over the next two years.

Scenario 3 – Assume NASA's FY99 Budget

Architecture Description

- Shuttle flies through 2010
- Shuttle held as backup through 2011
- NGLS commercial IOC in 2009
- NGLS flies commercial missions in 2009, ISS cargo in 2010, and assumes all ISS missions in 2011
- CRV deployed on Shuttle then NGLS
- ELV's continue to fly at reduced rates

NASA/OMB Decisions

- Technology risk reduction program initiated in fiscal year 2000
- ISS launch services award in fiscal year 2004 to allow commercial investment

Total Cost Savings: $6.5B (discounted) against Shuttle baseline

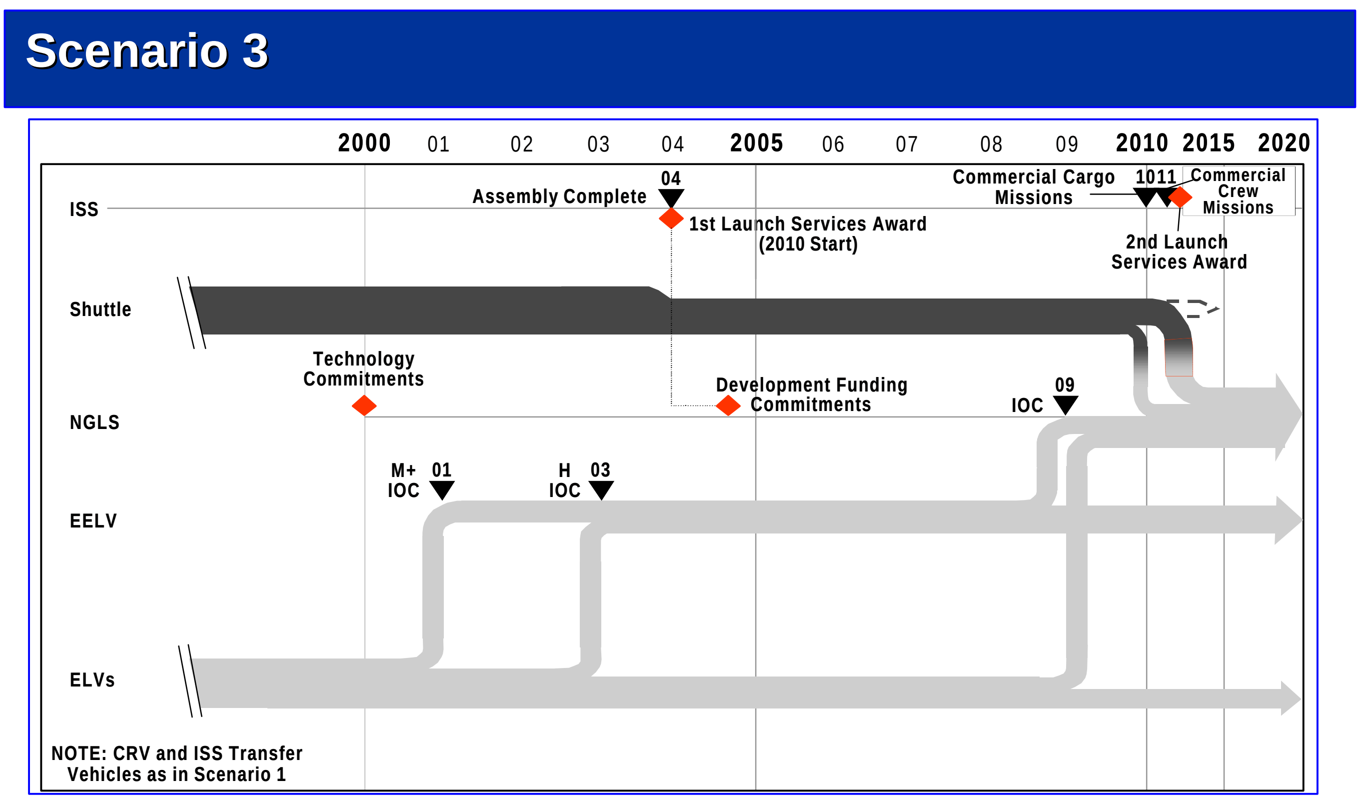

Figure 3.

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6. Cost Benefit Summary

We calculated key financial metrics (Figure 5) to evaluate the three optimized scenarios against the NASA budget guideline:

a) The 20-year, discounted cash flow for NASA human space flight

b) Annual operations cost, non-discounted, for "apples-to-apples" comparison against the $2.4B baseline.

c) Our estimate of the lowest likely human space flight out-year cost to NASA.

In the near term, NASA can achieve cost savings by continuing to operate and improve Shuttle. Through 2016, Scenario 1 provides the most cost savings.

By replacing Shuttle with the NGLS, Scenarios 2 and 3 both yield substantially lower steady-state recurring cost. However, the NASA commitments and investments to help bring the NGLS into operation must be counted against these out-year savings. By 2020, Scenarios 2 and 3 do provide lower NASA operating budgets for human space flight. Figure 8 illustrates that over the 20-year period the cumulative budgets are relatively similar ($24B to $26B) and all save against the current baseline.

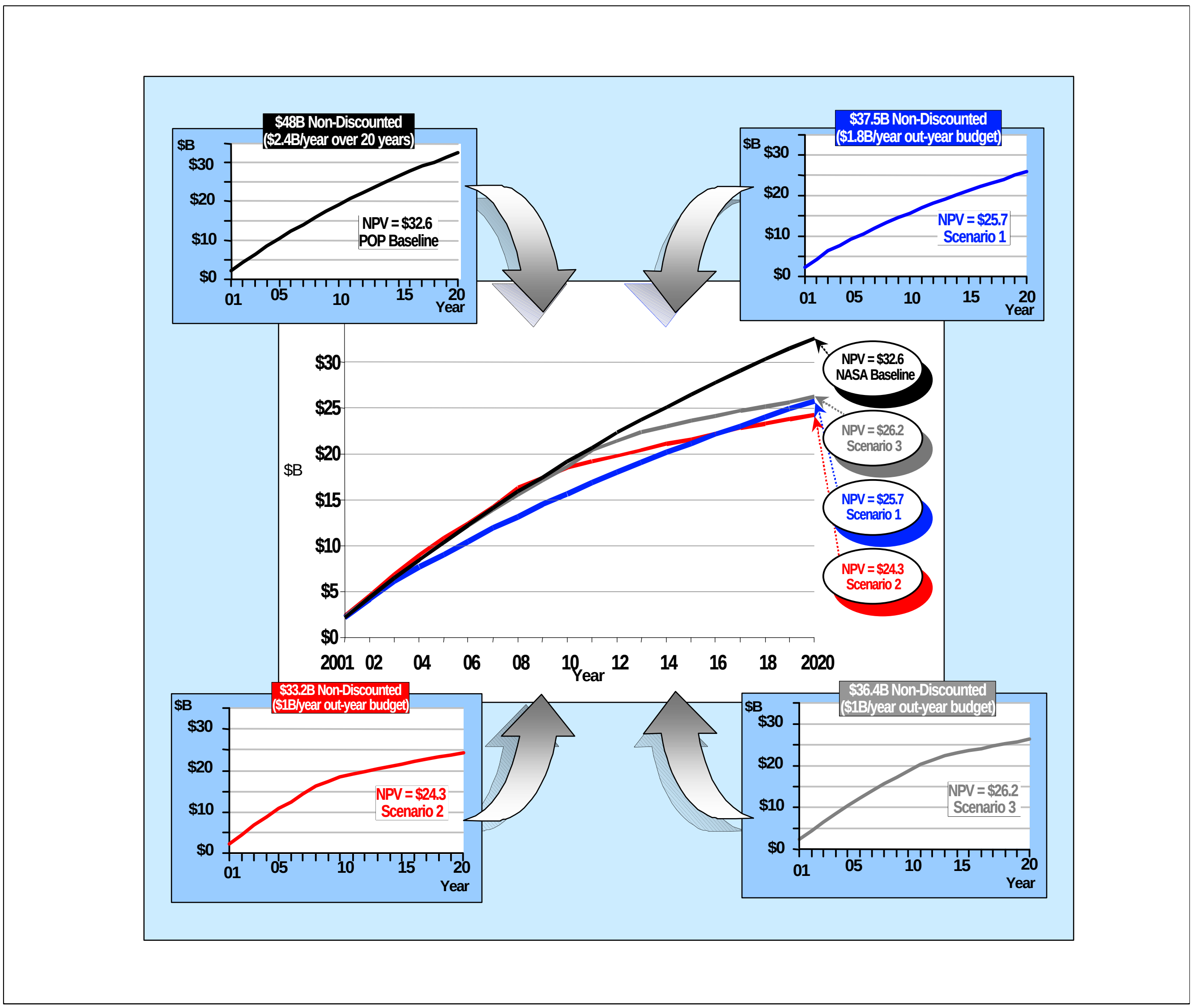

Figure 5. Human Space Flight Budget, Cumulative Discounted Cost Scenario Comparison

7. Key Findings

1. Human space flight will remain a unique government requirement for the foreseeable future.

2. Shuttle operating costs can be reduced to $1.8B annually through upgrades and Space Flight Operations Contract cost reduction initiatives.

3. Required investment levels, market requirements, market uncertainty, and development risk are some of the key issues government and industry must resolve before deciding to replace Shuttle.

4. A commercially developed NGLS could reduce annual NASA operating costs to $1 billion and is a more cost effective system to replace the Shuttle than a commercially developed crew transfer vehicle on a human-rated ELV.

5. Developing the NGLS requires commercial practices, minimum government oversight, in-place technologies.

6. Closing the NGLS business case requires both government technology investment and advanced purchase commitments for launch services.

7. Based on requirements and fundamental, universally accepted business metrics, there is no market-driven business case for a human-rated NGLS at this time.

8. Boeing Recommendations

1. NASA should commit to Shuttle operations through at least 2010.
   - Enables investment decisions to sustain and improve Shuttle operations.
   - Acknowledges technical, budget, and investment constraints for a replacement system.

2. NASA should continue to invest in Shuttle upgrades to reduce near-term transportation costs.

3. NASA should continue to invest in a reusable first stage to ensure safety and reliability.

4. CRV should remain the lifeboat for ISS.

5. NASA should fund high-risk technologies that maximize downstream opportunities for competition.

6. NASA and industry should investigate the viability of commercial investment in human space flight on a regular basis.

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