1. System cost estimate: **Aerospaceplane (Gen 1.5)**

2. Cost estimate quality: Rough-order-of-magnitude (ROM) estimate

3. Assumptions:
   - 2015 state-of-the-art (TRL 6-9) technology readiness at beginning of engineering development
   - Gen 1.5 aerospaceplane is an upgrade of the Gen 1 aerospaceplane system; not a new Gen 2 system.
   - Primary focus of the update is to decrease turn-around time and recurring costs and to change the orbiter to internal payload carriage.
   - Prime contractor-led system development.
   - Work-year cost is $250K (US).
   - Takeoff gross weight increases modestly to 3M lb (3%) based on assumed 3% increase in booster engine sea-level thrust.
   - Orbiter design is modified to include internal payload bay accommodating 15 ft diameter by 30 ft long cargo optimized for SBSP component delivery.
   - Orbiter delivered payload increases to 30,000 to 50,000 lb from 25,000 lb for the Gen 1 system; assume 40,000 lb for cost purposes.
   - Orbiter design is modified to include improved thermal protection system (TPS) and longer-life engines and high-cost subsystems.
   - Orbiter airframe and propellant tanks are redesigned to utilize materials other than the aluminum assumed in the Gen 1 design for decreased structural weights. Recovered weight translates directly to payload after increased weight for internal payload bay is accounted for.
   - Flight load measurements and internal loads and strain measurements of the Gen 1 orbiter enables reoptimization of the airframe and TPS to recover weight margin included in the Gen 1 design. Recovered weight translates directly to increased payload.
   - Booster airframe and propellant tanks are redesigned to utilize materials other than the aluminum assumed in the Gen 1 design and to take advantage of the improved understanding of design loads and usage.
   - Based on redesigned booster, booster-orbiter separation velocity is adjusted higher decreasing required orbiter propellant fraction and reducing orbiter structural weights and on-orbit maneuvering propellant requirements. Resulting increase in payload fraction increases delivered payload.
   - Booster engines are upgraded for increased thrust and increased life between engine replacements.
   - Booster and orbiter maintenance access is improved to decrease maintenance work-hours.
   - Booster and orbiter ground processing procedures are improved to decrease turn-around time and reduce maintenance work-hours.
   - Increased use of health monitoring is used to decrease required post-flight direct-touch inspections.
   - Learning curve is applied to production system and replacement engine costs (assume 20% average reduction in production cost)
   - Indirect support work-hours are assumed to be 50% of the direct support work-hours rather than 100% as with the Gen 1 systems.
   - Booster and orbiter development costs are 25% of the Gen 1 development costs based on limited configuration redesign and the fact that the contractor’s design team is now knowledgeable and experienced with the design.
   - Booster and orbiter engine upgrade development cost is 50% of Gen 1 engine development costs based on the need for primarily selected component life testing and less full engine testing.
   - Booster and orbiter direct support work-hours are 33% of Gen 1 support work-hours based on Gen 1.5 redesign for maintainability compared with the Gen 1 estimates of support work-hours that were based on Space Shuttle orbiter historical data.

M. Snead, 8 Aug 2007, mike@mikesnead.net
• Development and production adjusted costs include 15-20% reserve, as did the Gen 1 cost estimates.
• 10 flight systems are produced plus ground test and major component spares.
• FOC system flights per year: 80
• FOC fleet capacity per year: 1,600
• Fleet lifetime capacity (20 years): 32,000
• $3M for spares and propellants per mission.

4. Cost elements:
• Booster and booster main engines development and production costs
• Orbiter and orbiter main engines development and production costs
• Complete booster/orbiter recurring FOC costs

5. Adjusted development work-years (U.S. government business-as-usual - BAU) per system type:
• Booster: 14,300
• Orbiter: 10,400
• Booster engine: 8,500
• Orbiter engine: 3,700
• Total: 36,900
• Integration factor: 1.17 (4 elements – booster, orbiter, spaceplane, and cargo container)
• Adjusted total: 43,200
• Development cost: $10.8B
• Reduced development cost based on using stated cost-optimized assumptions: $6.5B ($5.2 + $1.3B reserve)

6. Production work-years (U.S. government BAU) per system type and no. of equivalent units:
• Booster: 15,500 (12)
• Orbiter: 20,000 (12)
• Booster engine: 7,000 (42)
• Orbiter engine: 2,900 (42)
• Total: 45,400
• Integration factor: 1.08 (4 elements)
• Adjusted total: 49,000
• Production cost: $12.2B
• Reduced development costs based on improved manufacturing capabilities relative to 1960’s-1980’s historical data: $7.4B

7. Cargo recurring operations cost per mission:
• Booster direct support work-hours: 7,900
• Orbiter direct support work-hours: 9,800

8. Total 20-year non-recurring and recurring costs for 2 types of Gen 1.5 aerospaceplanes:
• Development: $13B (includes 15-20% reserve)
• Production: $14.8B (includes reserve)
• Recurring: $256B
• Total: $284B (includes reserve)
• Avg. cost per year: $14.2B for 1,600 flights
• Avg cost per mission: $9M
• Avg cost per lb of payload: $225