Spacefaring Logistics Infrastructure Fact Sheet

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.

Gen. 1.5 aerospaceplane

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- 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: $12.2
    - 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
    - Combined direct support work-hours: 17,700
    - Assumed indirect support work-hours: 8,900
    - Total support work-hours: 26,600
    - Delivered payload (net) to space logistics depot: 40,000 lb
    - Total support work-hours (cargo mission) per lb delivered: 0.67
    - Support cost per work-hour (1,840 hours per year): $136
    - Support cost per lb of payload delivered: **$90**
    - Booster engine average work-years to produce: 100
    - Booster engine average cost: $25M
    - Booster no. of engines: 4
    - FOC life of engines: 100
    - Booster engine cost per mission: $1M
    - Booster engine r cost (FOC) per lb of payload delivered: **$25**
    - Orbiter engine average work-years to produce: 33
    - No. of orbiter engines: 4
    - Orbiter engine average cost: $8.3M
    - Orbiter engine cost (FOC) per mission: $0.3M
    - FOC life of engines: 100
    - Orbiter engine cost (FOC) per lb of delivered payload: $8
    - Non engine spares and propellants per mission per lb of delivered payload: $75
    - FOC cost per lb of delivered cargo: $90 + $25 + $8 + $75 = **$200**
    - FOC cargo mission recurring cost: ~**$8M**
    - FOC annual fleet recurring cost: $12.8B for 1,600 flights
    - FOC annual fleet payload capacity: 32,000 tons
    - Lifetime fleet recurring cost: $256B
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**