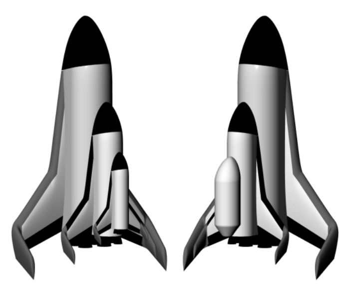
# Spacefaring Logistics Infrastructure Fact Sheet

1. System cost estimate: **Aerospaceplane (Gen 1)**
2. Cost basis:
   - Closed Air Force sizing analysis of two-stage aerospaceplane system with system weight estimates
   - Historical weight-based cost estimating relationships for development and production cost; yields work-years required
   - Recurring direct labor based on Space Shuttle orbiter actual data; yields work-hours required
   - Cost estimate quality: Rough-order-of-magnitude (ROM) estimate
3. Assumptions:
   - 2007 state-of-the-art (TRL 6-9) technology readiness at beginning of engineering development
   - Prime contractor-led system development
   - 15% empty weight margin applied to booster and orbiter empty weights (integrated into the sizing/performance analysis) except for booster and orbiter main engines
   - Main engine nominal thrust set at 92%
   - Airframe structure is standard aluminum design
   - Orbiter thermal protection system is current (best) Space Shuttle orbiter technologies
   - Passenger spaceplane recurring costs equivalent to orbiter recurring costs
   - Indirect labor costs assumed equal to direct labor costs
   - Main engine replacement at IOC is 10 missions
   - Main engine replacement at FOC is 25 missions
   - $5M for booster and orbiter (combined) non engine spares and propellant costs per mission (~1% of booster and orbiter production cost for spares each mission)
   - $2M for passenger spaceplane spares and propellant costs per mission
   - Booster main engines are 120% RD-180 equivalent LOX/kerosene engines
   - Orbiter main engines are RD-120-equivalent LOX/kerosene engines
   - Work-year cost is $250K (US)
   - Cost-optimized design as described (e.g., use of TRL 6-9 technologies, modern manufacturing processes, etc.) enables 40% cost reduction from historical U.S. government business-as-usual actual program costs
   - Two types required for assured space access (meaning all development and production costs are doubled)
   - Three operational systems of each type fielded for six systems total; two operational passenger spaceplanes per type
   - No credit is taken for use of derivatives of existing engines
   - Because baseline historical data includes 15-20% program cost growth, projected costs based on this data includes 15-20% program cost reserve
   - No cost reduction due to learning curve is taken for FOC support costs or replacement engine production costs
4. Cost elements:
   - Booster and booster main engines development and production costs
   - Orbiter and orbiter main engines development and production costs
   - Passenger spaceplane and spaceplane main engines development and production costs
   - Cargo container development and production costs
   - Complete booster/orbiter/spaceplane recurring IOC and FOC costs
5. Development work-years (U.S. government business-as-usual- BAU) per system type:
   - Booster: 57,200
   - Orbiter: 41,400
   - Passenger spaceplane: 42,000
   - Cargo container: 8,300
   - Booster engine: 17,000
   - Orbiter engine: 7,400
   - Spaceplane engine: 1,000



***Gen. 1 aerospaceplane with passenger spaceplane (left) and cargo container*** (right)

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- Total: 174,300
- Integration factor: 1.17 (4 elements – booster, orbiter, spaceplane, and cargo container)
- Adjusted total: 204,000 (Note: For comparison, the Space Shuttle orbiter and SSME required 93,000 work-years)
- Development cost: $51B
- Reduced development cost based on using stated cost-optimized assumptions: **$31B** ($24.5B + $6.5B reserve)

6. Production work-years (U.S. government BAU) per system type and no. of equivalent units:
   - Booster: 9,700 (5)
   - Orbiter: 12,500 (5)
   - Passenger spaceplane: 5,000 (3)
   - Cargo container: 1,500 (7)
   - Booster engine: 2,900 (14)
   - Orbiter engine: 1,200 (14)
   - Spaceplane engine: 200 (7)
   - Total: 33,000
   - Integration factor: 1.08 (4 elements)
   - Adjusted total: 35,700
   - Production cost: $8.9B
   - Reduced development costs based on improved manufacturing capabilities relative to 1960's-1980's historical data: **$5.4B**
7. Cargo recurring operations cost per mission:
   - Booster direct support work-hours: 23,700
   - Orbiter direct support work-hours: 29,300
   - Combined direct support work-hours: 53,000
   - Assumed indirect support work-hours: 53,000
   - Total support work-hours: 106,000
   - Delivered payload (net) to space logistics depot: 25,000 lb
   - Total support work-hours (cargo mission) per lb delivered: 4.25
   - Support cost per work-hour (1,840 hours per year): $136
   - Support cost per lb of payload delivered: **$575**
   - Booster engine average work-years to produce: 124
   - Booster engine average cost: $31
   - IOC life of engines: 10 missions
   - Booster engine avg. cost per mission (IOC): $3.1M
   - No. of booster engines: 4
   - Booster engine cost (total @ IOC) per mission: $12.4M
   - Booster engine cost (IOC) per lb of delivered payload: **$500**
   - FOC life of engines: 25
   - Booster engine cost (FOC) per lb of delivered payload: **$200**
   - Orbiter engine average work-years to produce: 52
   - IOC life of engines: 10 missions
   - No. of orbiter engines: 4
   - Orbiter engine avg. work-year prorated per mission (IOC): 5.2
   - Orbiter engine average cost: $21.5M
   - Orbiter engine avg. cost per mission (IOC): $1.3M
   - Orbiter engine cost (total @ IOC) per mission: $5.2M
   - Orbiter engine cost (IOC) per lb of delivered payload: $200
   - FOC life of engines: 25
   - Orbiter engine cost (FOC) per lb of delivered payload: $80
   - Non-engine spares and propellants per mission per lb of delivered payload: $200
   - IOC cost per lb of delivered cargo: $575 + $500 + $200 + $200 = **$1,475**
   - IOC cargo mission recurring cost: ~**$37M**
   - FOC cost per lb of delivered cargo: $575 + $200 + $80+ $200 = **$1,060**
   - FOC cargo mission recurring cost: ~**$26M**
8. Passenger transport recurring operations cost per mission:
   - Passenger spaceplane direct support work-hours: 29,300
   - Passenger spaceplane indirect support work-hours: 29,300
   - Total support work-hours: 58,600
   - Total support cost: $8M
   - Spaceplane engine average work-years to produce: 29
   - Engines per spaceplane: 2
   - FOC life of engines: 25
   - Spaceplane engine cost per mission (FOC): $0.3M

- Spaceplane mission recurring cost (FOC): $8M + $0.3M + $2M = $10.3M
- Total passenger transport mission cost (FOC): $26M + $10.3M = ~$36M
- Passenger transport cost (FOC): **$3.6M**

9. U.S. government annual recurring mission costs (FOC):
   - 15 cargo missions: $390M
   - 5 passenger transport missions: $180M
   - Total annual cost: **$570M**
   - 20 years total recurring cost: **$11.4B**
10. Total 20-year non-recurring and recurring costs for 2 types of Gen 1 aerospaceplanes:
    - Development: $62B (includes 15-20% reserve)
    - Production: $10.8B (includes reserve)
    - Recurring: $11.4B
    - Total: **$84.2B (includes reserve)**
    - Avg. cost per year: **$4.2B**
    - Current annual U.S. government expenditures on space access: $5-6B ($100B-$120B over 20 years)
    - Avg. cost per mission: **$210M**
11. Commercial use of Gen 1 aerospaceplanes:
    - FOC flight rate per system: ~24 missions per year (nominally every two weeks plus time for depot operations)
    - FOC fleet annual flight capacity: ~140
    - U.S. government current annual mission needs: ~20
    - Annual no. of additional missions available for additional government and private use: ~**120**
    - Annual possible revenue (FOC recurring costs + 10% profit): $3.7B (80%/20% split for cargo/passenger)
    - 20-year possible revenue: ~$74B
12. Notes:
    - Details of the cost estimate were published in the AIAA paper "Cost Estimates of Near-Term, Fully-Reusable Space Access Systems," James M. Snead, 2006. This paper is available at http://mikensnead.net on the space resources page.
    - The cost-engineering methodology used for the development and production cost estimates were based on Koelle's Handbook of Cost Engineering for Space Transportation Systems.
    - Additional systems procured beyond three operational systems are for production article ground test and major component spares.

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