Part 2

C·O·S·T ENGINEERING™

„Design and Marketing of Rockets"

Lecture Series given by Dr.-Ing. Robert Alexander Goehlich

- Part 2: Cost Engineering Methods -

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General
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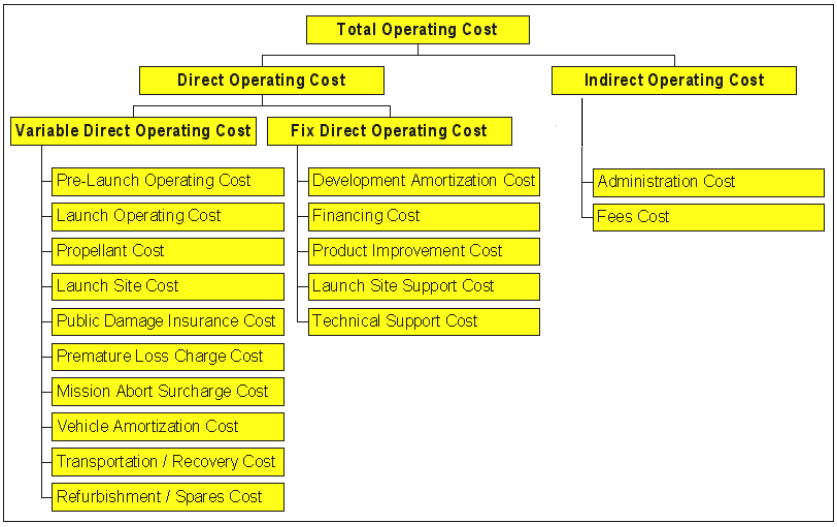
General
Goal of Today‘s Lecture

„You will learn about the main cost items caused by space transportation systems.“

Cost Items

Overview of Operating Costs



Variable DOC

Pre-Launch Ground Operating Cost

Pre-launch ground operating cost includes ground transportation, vehicle assembly, maintenance, fueling and launch preparations. It is strongly influenced by the vehicle size, launch mode (vertical or horizontal) and launch rate.

Example:

150 M$/launch for Space Shuttle (95th flight, 6 LpA)

Rollout of Space Shuttle (NASA)

Variable DOC

Launch and Mission Operating Cost

Launch and mission operating cost include the communication system and personnel and software used by a mission control center. It depends on the vehicle complexity, crew size and stay time in orbit.

Example:

80 M$/launch for Space Shuttle (95th flight, 6 LpA)

Launch of Space Shuttle (NASA)

Variable DOC

Propellant Cost

Propellant cost depends on the quantity, type and boil-off-losses of the propellant.

Example:

3 M$/launch for Space Shuttle i.e LH2, LOX, Orbital Maneuvering System (OMS) and Rocket Control System (RCS) Propellants (95th flight, 6 LpA)

Space Shuttle Main Engine (NASA)

Variable DOC

Launch Site User Fee Cost

Launch site administration, facility maintenance, range stations and safety provisions make up the launch site user fee cost. Government controlled and financed launch sites usually take a user fee from commercial launch operators.

Example:

1 M$/launch for Ariane 5 (in addition to a fixed annual fee of 4 M$).

ELA1 launch zone at Europe's spaceport in French Guiana (ESA)

Variable DOC

Public Damage Insurance Cost

There is normally a governmental requirement for a launch service provider to take insurance against public damage.

Example:

For a $100 million coverage for damage caused by falling pieces of a launch vehicle, insurance cost is typically about $0,1 million (D.E. Koelle, 2000).

The first Delta III rocket exploded on take-off (US Air Force)

Variable DOC

Premature Loss Charge Cost

There is a small chance that a catastrophic failure leads to a premature vehicle loss. This risk must, however, be covered by insurance or by a reserve fund contribution (self-insurance).

Example:

Space Shuttle's statistical vehicle loss rate is less than 0,01 (1 out of 100 flights) while the statistical loss rate of civil aircraft is 0,000 001 (1 out of 1 million flights).

On August 6, 1997, a Boeing crashed at Nimitz Hill, Guam (NTSB).

Variable DOC

Mission Abort Surcharge Cost

The failure to transport passengers to suborbit or orbit causes a free re-launch. However, complete cost of an aborted flight can be up to a factor 3 higher than that of a regular mission, taking into account the indirect cost resulting from necessary investigations and the service interruption.

Example:

The assumed abort rate for Reusable Launch Vehicles is 0,03 (1 out of 30 flights), while the abort rate for civil aircraft is 0,0003 (1 out of 3000 flights).

Take-off abort (Norris)

Variable DOC

Vehicle Amortization Cost

Vehicle amortization cost is based on the vehicle, rocket engine production cost and the number of reuses. Since production cannot be switched on and off according to program requirements, there are only two options: a continuous production activity for a high launch rate or a production in batches for a low launch rate.

Example:

3000 M$ for Space Shuttle Orbiter (1st Unit)

Space Shuttle Orbiter

Variable DOC

Transportation and Recovery Cost

Transportation costs are caused due to bad weather conditions, aborted launches or emergency landings.

Example:

The Space Shuttle Orbiter ferry transportation by a modified B747 from Edwards Air Force Base in California to Kennedy Space Center in Florida costs about $3,7 million (D.E. Koelle, 2000).

Modified B747 (NASA)

Variable DOC

Refurbishment and Spares Cost

Refurbishment means that reusable vehicles have to be taken out of regular service after a number of flights to undergo a detailed inspection and exchange of components before wear-out sets in (called off-line activity).

Example:

The vehicle system refurbishment cost per flight is about 2 % of production cost for the Space Shuttle Orbiter, while rocket engines refurbishment cost per flight for the SSME has been up to 11 % of production cost.

Kennedy Space Center (Iocui)

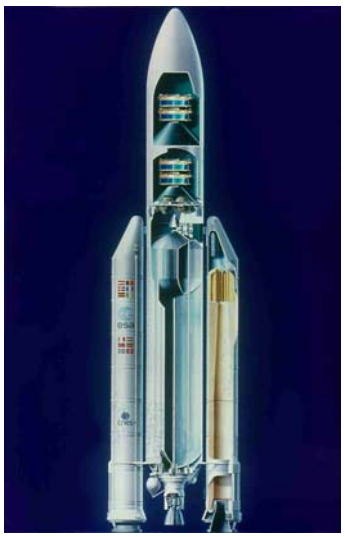
Fix DOC

Development Amortization Cost

Development amortization cost is linearly distributed over all launches of the fleet's vehicles. Depending on the kind of contracts, this cost is shared between enterprises and fiscal.

Example:

Development cost has been 3000 M$ for Ariane 5's Core Stage.



Schematic of the Ariane 5 spacecraft.

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Financing Cost

In case of a commercial project, financing cost is caused by a loan to finance development and operation cost until a positive cash flow is achieved.

Example:

Break-even point for launch systems is very high (10 - 20 years).

EZ-Rocket test (XCOR)

Fix DOC

Product Improvement and Technical Support Cost

Increasing reliability, maintenance and security causes product improvement cost, while trouble shooting, minor repairs, crew training, spares storage and documentation cause technical support cost.

Example:

16 M$/launch for Space Shuttle‘s technical system update.

Astronaut training in tank (NASA)

IOC

Administration and Fees Cost

A space launch system operator needs a certain staff for administration, system management, customer relations and marketing causing cost for travel, office equipment, fairs, publications, etc. Fees cost are all expenditures for fees and taxes, which are necessary for the operation.

Example:

Administration cost is 40 M$/launch for Space Shuttle.

Marketing of Space Shuttle (NASA)

Definition

Definition of Cost Engineering (Practice II)

Case A

- *Step 1: Build a Rocket within 15 minutes in a team.*
- *(Step 2): Cut costs of 50 % (by reducing material of 50 %) within 5 minutes.*

→ Cost is unimportant

Case B

- *Step 1: Build a Rocket within 15 minutes in a team by using only 50 % of material as used in Case A's Step 1.*

→ Design-to-Cost

Case C

- *Step 1: Build a Rocket within 15 minutes in a team by achieving minimum life-cycle costs.*

→ Cost Engineering

Review:

Compare results of Case A, B and C.

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