Professional Development Short Course On:

Reducing Space Launch Cost

Instructor:

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ATI Course Schedule: http://www.ATIcourses.com/schedule.htm

ATI's Reducing Space Launch Cost: http://www.aticourses.com/reducing_space_launch_cost.htm

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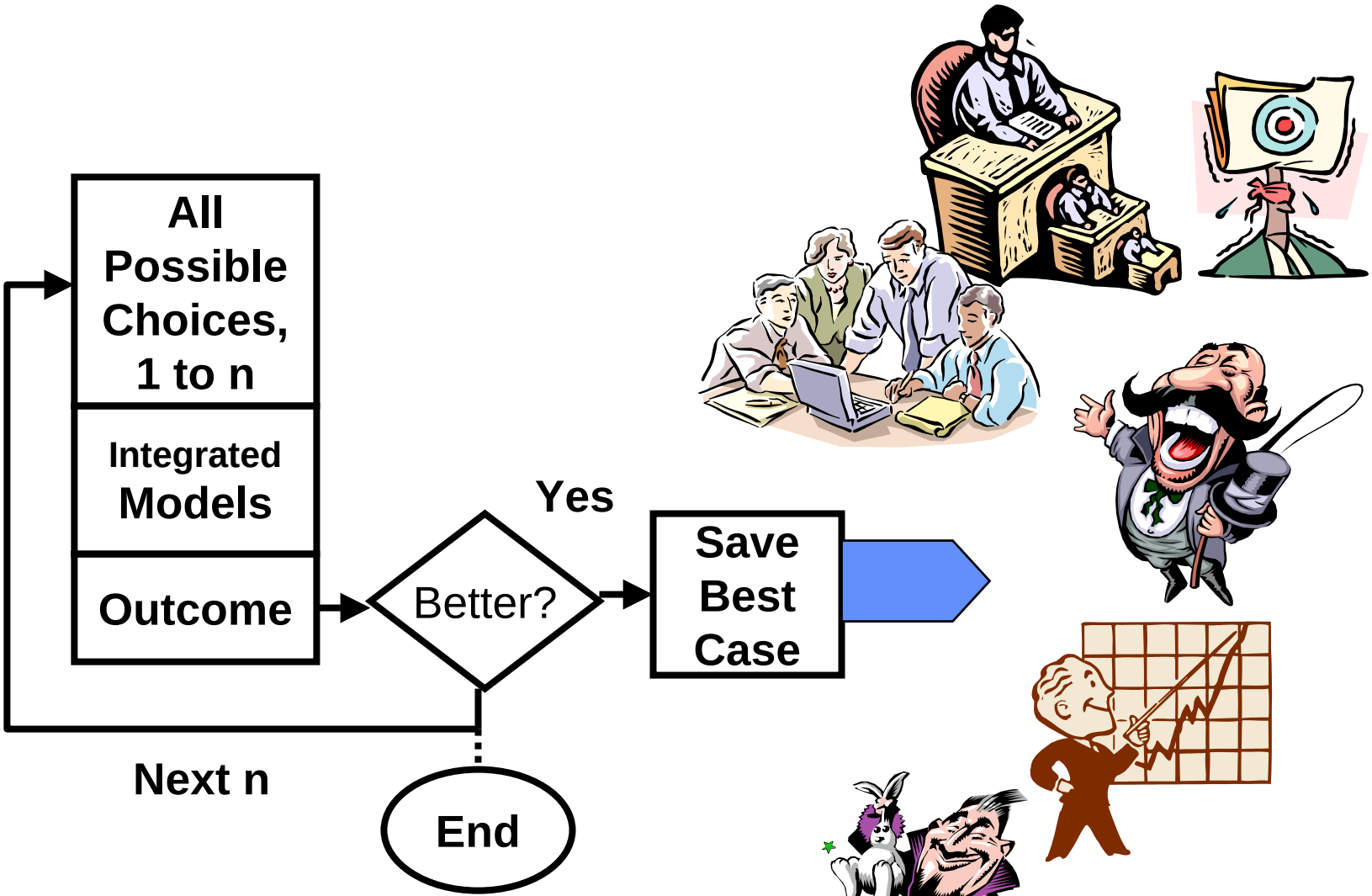
Reducing Space Launch Costs Class Sampler

This is the most advanced class available concerning the issues of reducing space launch costs. The same science-based principals are applied to both expendable and reusable systems. Strategies applicable to any concept that will reduce both Development and Operational costs are explained. Modeling as Trade Study tools are emphasized.

Concept of Algorithm Maturity Level

- **Algorithm Maturity Level (AML) is a metric**
  - **AML-1 Place holding conjecture, no valid algorithm known**
  - **AML-2 Conjecture, new algorithm with limited scientific basis**
  - **ACL-3 Conjecture, unproven algorithm with reasonable Scientific Hypothesis**
  - **ACL-4 Algorithm with Scientific hypothesis and some supporting evidence**
  - **ACL-5 Algorithm with scientific principal and significant supporting evidence**
  - **ACL-6 Algorithm Published, but not generally known or used**
  - **ACL-7 Widely used, but lacks rigorous peer review**
  - **ACL-8 Algorithm Peer reviewed and accepted with some controversy**
  - **ACL-9 Algorithm Peer reviewed and accepted throughout the community**

Concept of a Search Model



Cost Models Look Like and Equation

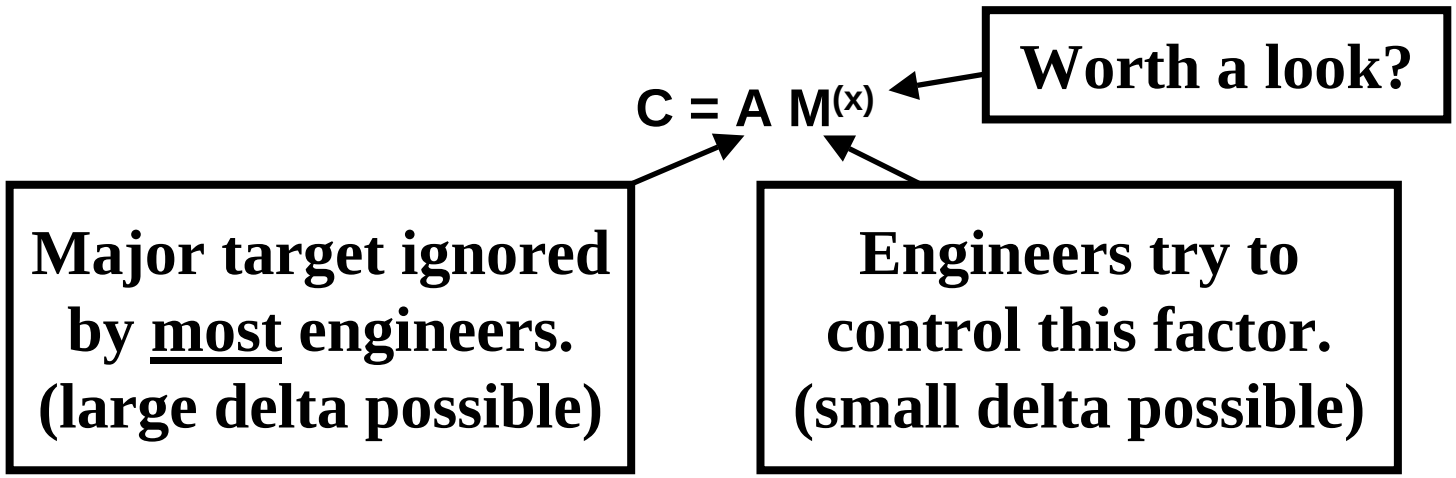
• $dV=Isp * g * ln(M/m)$	• $C = A (M)^x$
• An Equation	• A Model
• Exact Answer	• Ballpark (+/- 25%)
• Derived from Physics	• Derived from History
• Permanent	• Temporary
• Scientific (Mathematics)	• Scientific (Economic)

- **A cost model is based on historic observations reduced to algorithms**
  - **Based on** Past Successful **Experience**
    - **Useful as planning tool**

Cost Models look like equations, but they are not. Cost Models are the most critical element to be understood in the search for more economical Space Transportation choices and decisions.

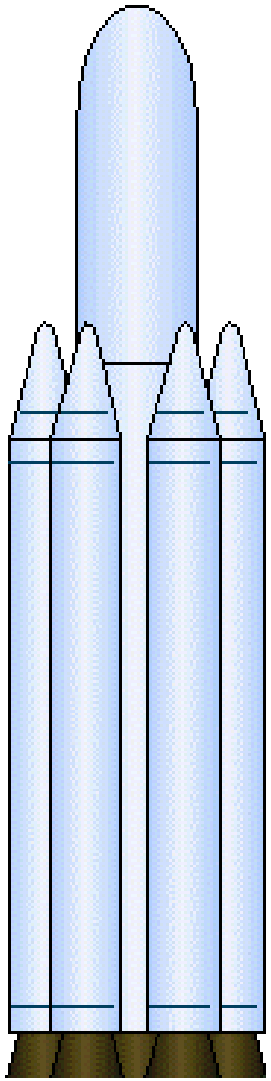
Doing Business Differently

- What about all the hundreds of ways of doing business that should lower the cost estimation relationship coefficient and exponent?



- The primary objective of doing business differently is to reduce the value of the coefficient A
  - Business strategies that reduce the value of A by a factor of ten or even two would make an enormous difference in costs

Reducto Ad Absurdum – Your Opinion



- Discuss the Microcosm Strategy
  - Seven identical rocket pods, each with seven identical engines, organized into three stages
    - 49 engines in all
      - Each engine so “cheap” that “a pound of hamburger costs more than a pound of thrust”
- Discuss the Conastoga Strategy
  - Seven Castor-4 solid rocket motors plus a Star-48 fourth stage
    - Only $73-million to develop
- Were the two strategies sound?
- Were they based on the same principal

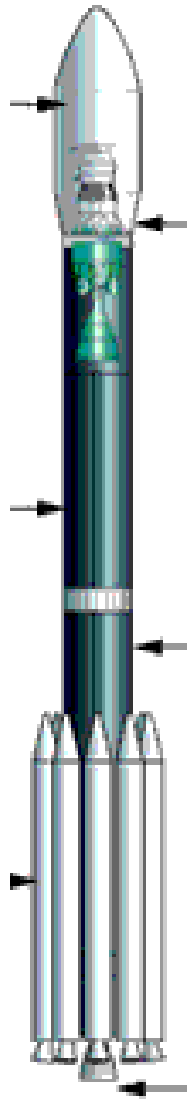
Operational Cost Elements

- **Direct Operational Costs** * Handbook of Cost Engineering (7.0)
  - **Pre-launch Ground Operations Cost**
  - **Propellant Costs**
  - **Flight and Mission Operations**
  - **Transport and Recovery Costs (if any) [like SRB]**
  - **Fees and Insurance**
- **Refurbishment and Spares**
  - **Vehicle**
  - **Engines**
- **Indirect Operational Costs**
  - **System Management & Administration (Shared)**
  - **Launch Site Support and Maintenance**
  - **Technical Assistance and Network Support**

Each of the above elements will be examined more Closely

Delta-II Analysis

- The Delta-II is probably the most cost-effective American launch vehicle
- Number of flights (302 as of 12/21/03 [inc Delta-III])
  - Effects of major modification and “improvements”
- Degree of modularity
  - Up to nine SRMs in stage one (50% of impulse)
    - Production rate up to 6 / month
    - 1,600 Older Castor IVB SRMs produced
- Degree of simplification – Relatively High
  - Simple solid rocket motors
  - Single engine 1950s technology core stage one
  - Pressure-fed 1950s technology stage two
  - Unguided SRM Stage three (option)



Pre Launch Operations Cost Model

- $C = 8 * M_o^{0.67} * L^{-0.9} * N^{0.7} * f_v * f_c * f_4$ [in man-years]
  - Where
    - M_o is gross mass of the vehicle
    - N is the number of stages
    - L = Launches per Annum
    - f_v = Launch Vehicle Type
      - For Multistage ELV using LOX/LH2 $f_v = 1.0$
      - For Multistage ELV using Other Liquid $f_v = 0.8$
      - For Multistage ELV using Solid Motors $f_v = 0.3$
      - For Automated RLV SSTO $f_v = 0.7$
      - Shuttle-Like Crewed RLV $f_v = 1.8$
    - f_c = Assembly and Integration Mode
      - For Vertical Assy & CO on-pad $f_c = 1.0$
      - For Vertical Assy & CO, transport to pad $f_c = 0.7$
      - For Horizontal Assy & CO, pad erection $f_c = 0.5$
    - f_4 = Learning Curve

Space Transportation is a *Virtual* Market

- There is no real space transportation market
  - The market is for ***Space Missions***
  - No one buys a ride to space without two other essential ingredients.
    - Payload and Operations
- Since launch vehicles are part of the overall space mission market, there must be a interdependent economic relationship.
  - You cannot look at the system of a space mission as independent elements
    - The launch, spacecraft and ground operations are part of the whole and indivisible

There is no market for empty dog food cans. When you want a case of dog food, you get a carton, cans and the dog food itself. The market is for *dog food*.

Commercialization of Launch Vehicles

- **The first launch vehicle generations were designed and developed under government contracts by aerospace companies, and then operated by same aerospace contractors under Government Agencies management**
  - **The government paid contractors to develop launch vehicles, which the same contractor then operated as a profitable business**

All risk of failed project and all sunk costs were borne by the government. All profit of developing a successful or a failed project went to the contractor. All profit from operating a successful project also went to the contractor

- **Why should the government take all the risks and pay a company to enter a non-risky profitable business?**

Reducing RLV Theory to Science

- **State the Problem : The cost of Space Transportation is excessively high because the expendable launch vehicles are thrown away after only one use**
- **Research the Problem : There is an alternative to the ELV systems in use since 1957, Reusable Launch Vehicles**
- **Form a Hypothesis : RLV systems will be more cost effective because the manufacturing cost of each vehicle can be spread over many missions**
- **Test the Hypothesis : According to the results of the Space Shuttle operations, and of detailed RLV modeling, the hypothesis is not supported at this time**
- **Draw a Conclusion From the Data : The reusable Space Shuttle did not achieve the intended low cost operations. In point of fact, Space Shuttle operations were far more costly than that of the ELV systems it intended to replace. Further, detailed modeling suggests the high cost of RLV development is not justified at this time, and operational savings are less than claimed by proponents**

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- Signal Processing & Information Technology
- Sonar & Acoustic Engineering
- Spacecraft & Satellite Engineering

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