Professional Development Short Course On:
Launch Vehicle Selection, Design, Performance & Use

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ATI Course Schedule:
ATI's Launch Vehicle Selection, Design, Performance & Use
http://www.ATIcourses.com/schedule.htm
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Launch Vehicle Selection, Analysis, Performance and Design Class Sampler

This class examines the Selection, Performance, Analysis and Design of Launch Vehicles. Emphasis is placed on issues of optimum selection of Launch Vehicles for any given mission. The features, performance and environments of Launch Vehicles that concern a payload are covered in depth.
Elements of Launch Services

Funding Organization
Spacecraft Project
Spacecraft Contractor

Payload Processing
Agency
Payload Processing
Contractor

Funding Organization
Launch Vehicle Project
Vehicle Contractor

Launch Operation

Ranges
• Launch
• Tracking
• Telemetry

Government Agencies
• NASA
• Air Force
• DOT, etc
Introducing Launch Ascent Environment

- The environments of an ascent from the ground to orbit are very severe, driving the mechanical design of spacecraft
  - Liftoff accelerations rise from 1-g to several times the force of gravity
  - Lateral g-forces build up to a peak as the launch vehicle passes through high wind shear and maximum dynamic pressure (max-q), where the acoustic noise is worse than standing on a speaker at a rock concert (140-150 db or more)
  - Vibration, driven by fluctuating engine thrust, is severe enough to disassemble improperly prepared hardware
  - Shock from explosive cutting of fairing halves and from explosive bolt release mechanisms
  - Venting from atmospheric pressure to vacuum in minutes
Minataur

- Four stage launch vehicle using old Minuteman first stage hardware
- Capacity - 1,408 pounds to 100 NM at 28.5 degree inclination
- Cost - $12.5 M
- Available only for US Government spacecraft or University satellites
  - No commercial payloads
- Stage 1 Motor M-55A 1 (Minuteman)
  Stage 2 Motor SR-19 (Minuteman)
- Stage 3 Motor Orion 50XL
- Stage 4 Motor Orion 38
The Japanese Strategy

- Japan did not use a weapons program as a springboard to a launch vehicle program
  - Japan bought rights to clone Delta launch vehicles during the 1970s
  - Gained experience with flights
  - Developed their own indigenous solid rocket launch vehicle capability
  - Took the leap to their own Indigenous high-technology LOX/LH₂ Heavy Lift Launch vehicle
- While the conventional wisdom of the time predicted a commercial success, the H-2 flopped from failures and high costs
Chinese Commercial Rockets

- Chinese Long March launch vehicles available for commercial launches
  - But not with any satellite containing even one USA component
- Questions of missile proliferation and export controversies (Loral, etc.) have hurt Long March
- China has launched several commercial satellites, but their safety record is embarrassing
  - China has a whole family of Long March Vehicles
Wall Street Got Burned

- Wall Street has always been skeptical of space ventures, except for geostationary satellite communications.
- Some companies have boldly invested in new ventures:
  - Motorola invested in Iridium, a $5-Billion cell-phone venture
    - Their stock is way down and Iridium was sold in bankruptcy for a half-cent on the dollar
  - Loral invested in a similar cell-phone venture
    - Their stock is way down and the business floundered
  - OSC invested in Orbcomm, a narrow-band communications venture
    - Their stock is way down and Orbcom needed bankruptcy protection
- The lesson investors learned is that “neat” ventures in space don’t always pan out, in fact the real track record is dismal.
### Selection Criteria Cafeteria Menu

- **Cost (Total Launch)**
- **Payload Performance**
  - Excess Capacity (Margin)
- **Type of Mission / Orbit / Priority if Dual Mission**
- **Secondary or Dual Payloads**
- **Payload Volume**
- **Orbital Accuracy & Errors**
- **Reliability**
- **Safety**
- **Launch Schedule Requirements and Integrity**
  - Dependability
  - Launch Window Integrity
- **SLV “Graceful Degradation Characteristics**
- **SLV Availability, Contract Terms / Conditions**
- **Actual (Physical) SLV System Availability**
- **Interface Suitability**
- **SC Housing Interface and Compatibility**
- **Launch Site Facilities and Location Suitability**
- **Launch Environments**
  - Launch Site and SLV Imposed Ground Environments
Meeting Schedule Requirements

• Most existing launch vehicles can be scheduled to support a specific space mission, unless there is a last-minute change
  – A typical space mission may be seven years in development
  – A typical launch vehicle order may require 30-months to fulfill
• Usually, the Launch Vehicle procurement is not on the Critical Path
• SELECTION OF A LAUNCH VEHICLE THAT IS UNDER DEVELOPMENT DOES EXPOSE THE MISSION TO SIGNIFICANT SCHEDULE RISK
Office of Commercial Space Transportation

• DOT Office of Commercial Space Transportation performs a Maximum Probable Loss (MPL) analysis of the mission
  – The largest loss ever experienced was $40 million for a Titan loss at Vandenberg Air Force Base
  – Government Property Loss
  – DOT has established Government Property MPLs of $75 million, $80 million and $80 million for Atlas, Delta and Titan sites at Cape Canaveral Air Station
  – The total of all third party losses in history is less than $10 million
  – DOT has established third-part MPLs of $164 million, $164 million, and $215 million for Atlas, Delta and Titan launches at Cape Canaveral Air Station
Rocket Control Systems

• Early rockets were stabilized, not guided or controlled
  – Stick or Fin
• Liquid rockets had good potential for control
  – Use a gyroscopic platform to maintain attitude reference
  – Use a feedback mechanism to correct errors (Guidance)
  – Use a program of planned trajectory (Navigation)
  – Use a control system to effect the feedback (Control)
  – Use a steering mechanism to effect the control
    • GN&C is Guidance Navigation & Control
• Early GN&C used to enable V-2 to hit distant targets
  – V-2 used combination jet vanes and fin controls with a chain-and-sprocket drive as the steering mechanism
    • Jet vanes (carbon-block deflectors in the exhaust gas stream) for good control at liftoff
    • Movable fin control, as airspeed increased
Classic Qualification Methods

- Qualification by Analysis
  - Independent analysis to verify the part will operate as required
- Qualification by Testing
  - A battery of tests to a higher level than the part will see in service
- Qualification by Demonstration
  - Demonstrate the operation in a realistic environment
- Qualification by Similarity
  - Qualifying a part based on very close similarity to an existing qualified part
  - Some instances – Qualification by Inspection

- Every part, component, assembly, subsystem and system on a spacecraft must be qualified to be on the spacecraft
Fundamentals of Selection

- Choice usually dictated by payload mass and orbit
  - Limited choices
  - Select by reliability
  - Cost
  - Mass Margin
  - Payload volume
  - Launch Environments
    - Once selected, the payload is designed according to the Launch Vehicle characteristics
    - Some Launch Vehicle characteristics may be negotiable
      - Upper stage motors
      - Fairing volume
      - Interface Options
Critical Elements of Selection

• The Selection process is simple, but is filled with traps that can cost millions to rectify
• Capacity is a major selection criteria
  – Be sure to include sufficient margin for spacecraft growth
• Reliability is critical
  – Be sure to understand what the real probability of mission success really are
• Cost is essential
  – Management is gaining the most benefit from the least amount of resources
• Know the schedule constraints from the time that early planning commences
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• Your employees may attend all or only the most relevant part of the course.

• Our instructors are the best in the business, averaging 25 to 35 years of practical, real-world experience. Carefully selected for both technical expertise and teaching ability, they provide information that is practical and ready to use immediately.

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