Orbital Space Plane:
An Application of Nathasit Gerdsri’s Model to NASA decision

EMGT 530/630
Decision Making-Winter 2004

Team 4
Voraphol Attavavuthichai
Gary Ficek
Wararat Leesirikun
Sarabjeet Waraich
Natchanan Wathanachinda
Acknowledgements

• Dr. Dundar F. Kocaoglu  
  Portland State University

• Nathasit Gerdsri  
  Portland State University

• Robert Awshee  
  Senior Mechanical Engineer, Cape Canaveral Air Force Station, FL (NASA sub contractor)
Define the Problem

• NASA has been considering replacing Space Shuttle since 1995
• Increased urgency since Columbia’s catastrophic failure February 1, 2003
• NASA issues RFP outlining Eleven Level-1 Design requirements for OSP design concepts
  – Very broad in nature (deadline, safety etc.)
• Three primary contractors selected to study next-generation space transportation
Scenario

• We are an independent consulting group
• Asked to evaluate the proposals utilizing decision analysis technique and provide advise to NASA

CONTEXT

• The selected OSP spacecraft (s) will function as a CRV, CTV and supply support
• The technology will provide a bridge to the future by serving as a foundation for future exploration missions.
• Designed with the crew in mind, to include safety in all phases of flight
• The vehicle must be able to support extended lunar missions and eventually include possible lunar take off (NASA).
Methodology

- Literature research of each alternatives
  - Collaborate Data
  - Defining the Criterion
  - Defining the Factors
  - Design the Hierarchical Decision Model
  - Assigned the relative weights
  - Implement the Hierarchical Decision Model
  - Results and Conclusion
  - Expert Judgments
  - Non-Expert Judgments
The Alternatives

- Alternative 1: The proposal from Lockheed Martin
- Alternative 2: The proposal from NASA Rockwell
- Alternative 3: The proposal from Boeing Integrated Defense Systems
A1. Lockheed Martin-OCS Joint Venture

- One smaller, more advanced spacecraft
- Capable of light payloads
- Capable of transporting small crew
- Lift-body Design
- Advanced and experimental technologies
A2. Upgrade the Space Shuttle Fleet
(NASA/Rockwell)

- Keep the Shuttle in operation until 2020 when a 3rd generation technology can replace it.
- Capable of transporting 7+ crew and heavy payloads.
- Mature technologies
A3. Boeing Integrated Defense Systems

- Two separate space vehicles
  - One exclusively for crew rescue and transportation (Apollo capsule design)
  - One cargo transport space craft (X-37 Robotic design)
- Mature, advanced and experimental technologies
Six Main Criteria

- Selected from NASA Level-1 OSP Design Requirements (Feb. 2003)
  - Preliminary literature search to determine availability of data
  - Selected 6 out of 11 criteria
  - Based Selection on:
    - Likelihood conclusions could be drawn from open-source data & basic design characteristics (similar technique in study of commercial space transportation vehicles by R. A. Goelich, Keio University)
Concept & Design Preferences

• Important for judging criteria & factors
• Determined from comments made at Congressional Hearings
  – Dialog of NASA officials
  – Congressman, Bush Admin. Officials
• Expert commentary and critique
  – Journals, Transcripts of Interviews
  – Pro-Cons of design characteristics
• Understanding of basic design characteristics
Factors: Subjective Judgment

- Factor = Sub-criteria
- Purpose of factors is to dissect each main criterion for a more accurate analysis
- Quantify weights for each factor
  - Judged the relative magnitude of specific factor compared to most important factor
  - Subjective judgment based on context, and concept and design preferences
Ranking Factors

• Six different descriptive conventions
• Ratio Scale
  – 0-100
• Straight Method of Scaling:
  – Scores indicate the condition of the alternative relative to the factor (similar to a utility value)
  – Higher number is better
Hierarchical Decision Modeling

Orbital Space Plane

Criteria 1
- F6
- F5
- F4
- F3
- F2
- F1
- Measured of A3
- Measured of A2
- Measured of A1

Criteria 2
- F12
- F11
- F10
- F9
- Measured of A3
- Measured of A2
- Measured of A1

Criteria 3
- F5
- F4
- F3
- F2
- F1
- Measured of A3
- Measured of A2
- Measured of A1

Criteria 4
- F8
- F7
- F6
- F5
- F4
- F3
- Measured of A3
- Measured of A2
- Measured of A1

Criteria 5
- F8
- F7
- F6
- F5
- F4
- F3
- Measured of A3
- Measured of A2
- Measured of A1

Criteria 6
- F8
- F7
- F6
- F5
- F4
- F3
- Measured of A3
- Measured of A2
- Measured of A1

Measured of Alternative 1
- Measured of Alternative 2
- Measured of Alternative 3
Alternative Evaluation

- Define:
  - \( V_i \) = Value of alternative (i) for the OSP project
  - \( W_n \) = Relative importance of criteria (n) with respect to the OSP objective
  - \( F_{mn} \) = Relative importance of factor (m) with respect to criterion (n)
  - \( U_{(vi,mn)} \) = Utility value of the performance and physical characteristics of alternative (i) along factor (m) of criteria (n)

\[
V_i = \sum_{n=1}^{6} \sum_{m=1}^{M} W_n \cdot F_{mn} \cdot U_{(vi,mn)}
\]
Measurement 1: Six Main Criteria

Criteria 1: The proposed spacecraft (s) must be fully operational by 2008.
Criteria 2: The spacecraft will have a lower risk than the Space Shuttle by 2008.
Criteria 3: Less time to prepare and launch than the space shuttle
Criteria 4: The spacecraft must have increased maneuverability than the Space Shuttle
Criteria 5: Less cost to operate, launch and maintain than the Space Shuttle
Criteria 6: Capable of landing at a targeted site.

$$\sum_{n=1}^{6} w_n = 1.0, \ w_n > 0$$
Measurement 2: 44 Factors

- Determine the relative impact of factor \((m)\) associated with criterion \((n)\)

\[
\sum_{m=1}^{M} f_{mn} = 1.0 \quad , \quad f_{mn} > 0
\]
Measurement 3: Performance and Physical Characteristics

- The characteristics of factors cannot be verified as a linear and a proportional function.

\[ 0 \leq U (v_{mn}) \leq 100 \]

For each combination of factor (m) and criteria (n)
Results

Pair Wise Comparison (PWC)

- Score individual alternatives
- Implement model
- Score
  - Boeing 71.61
  - Lockheed 58.74
  - Rockwell 64.27
Conclusion

- We were able to understand the preferences of the decision-makers via qualitative research methods.
- We were able to make subjective judgments based on open-source data and basic design characteristics.
- By combining PWC and Multi-criteria analysis we were able to determine the combined relative importance of six main criteria and 44 factors for each of the proposals.
- We were able to recommend the best alternative based on an explicit and defendable method.
Thank you!