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

EMGT 530/630
Decision Making-Winter 2004

Team 4

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Agenda

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- Results
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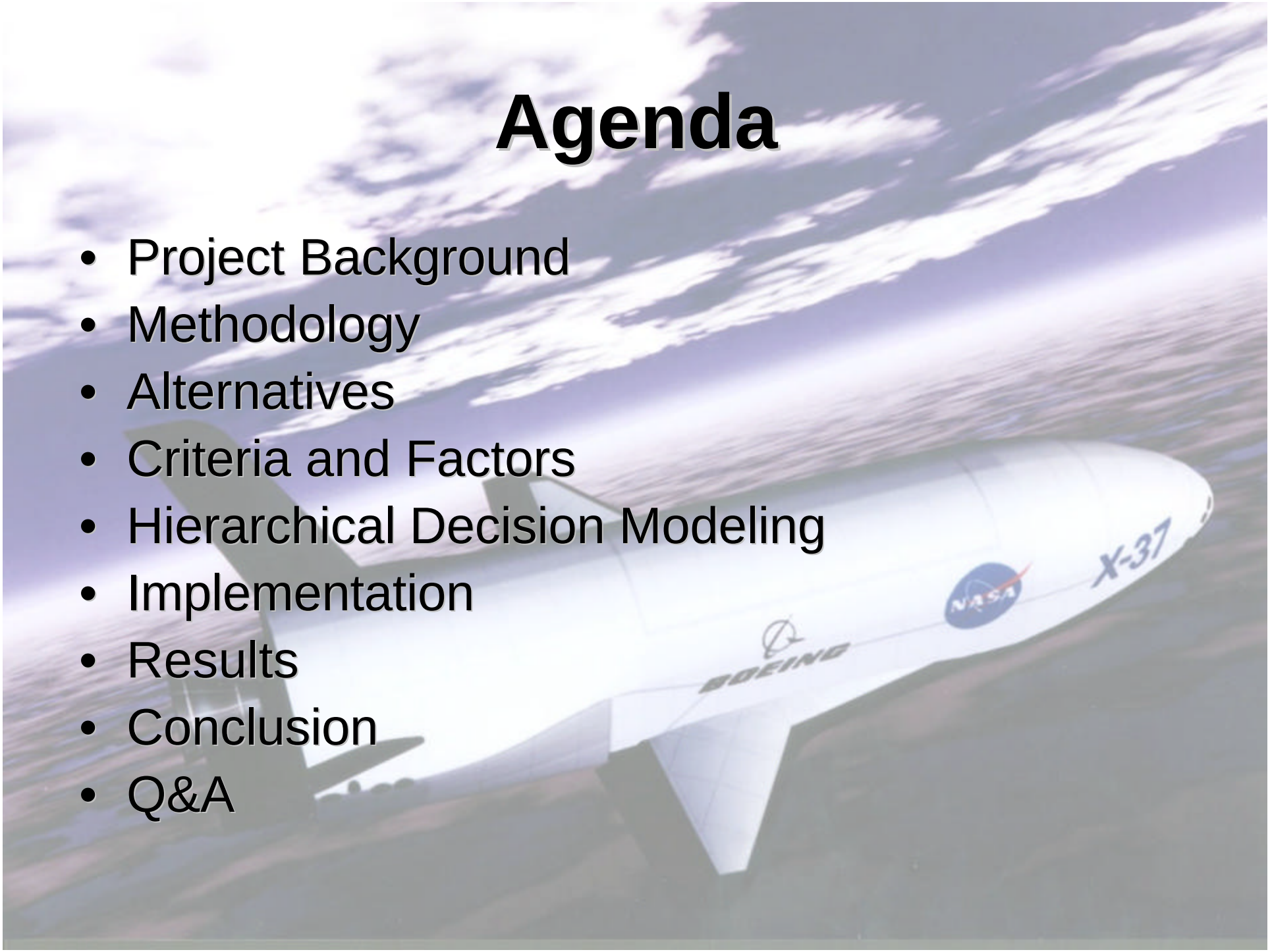


Define the Problem

- 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

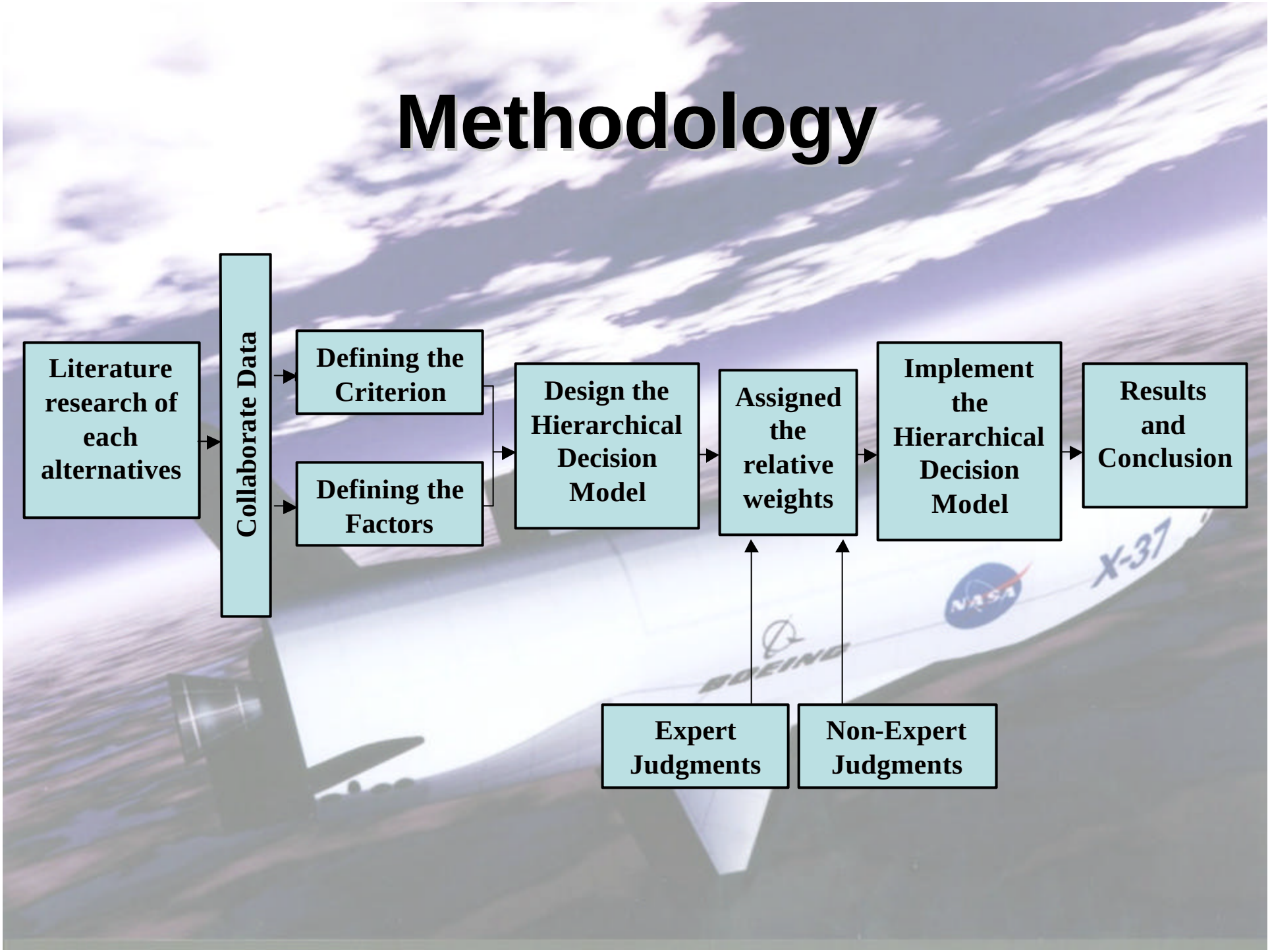
Scenario

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

CONTEXT

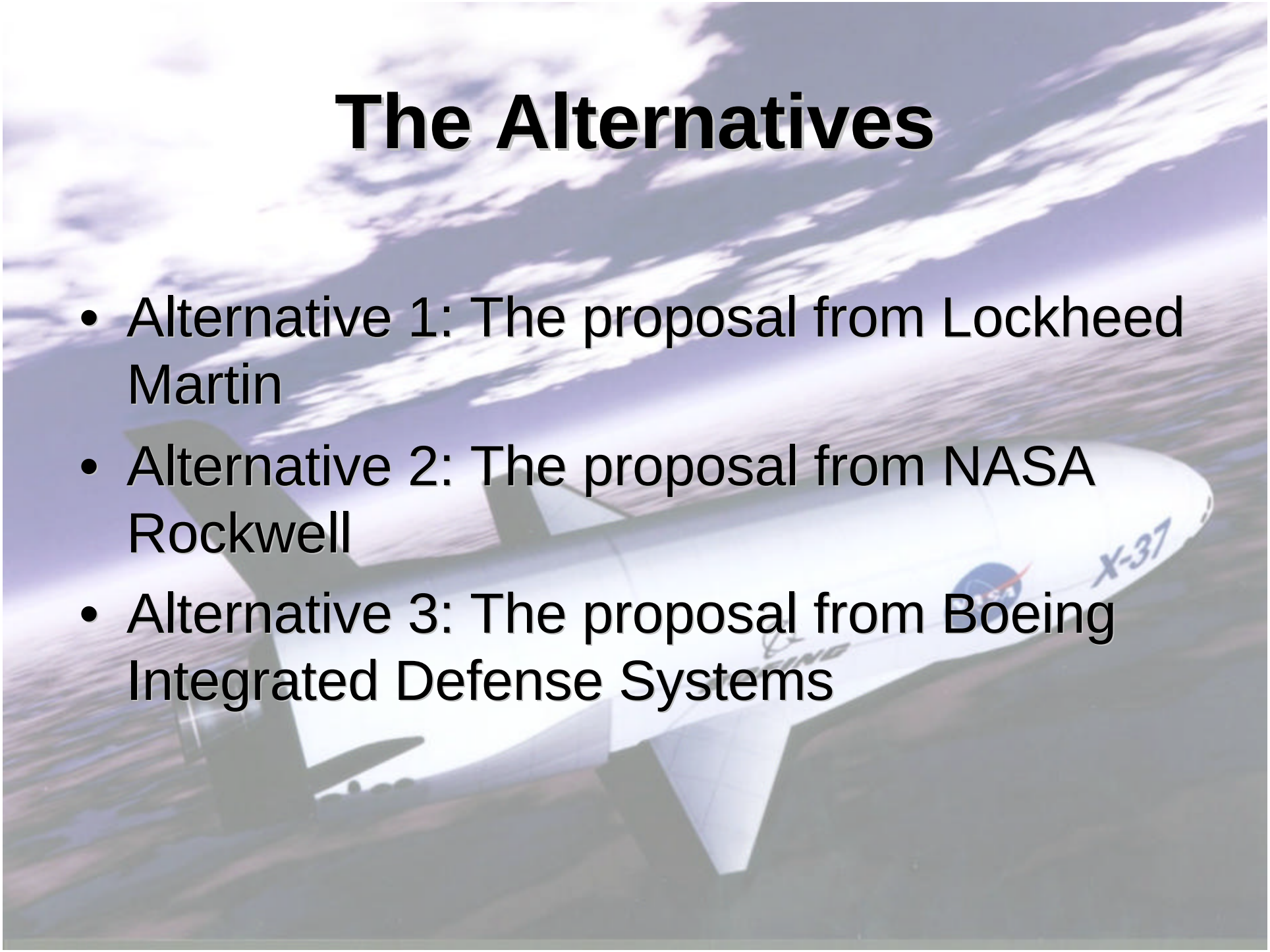
- The selected OSP spacecraft (s) will function as a CRV, CTV and supply support
- The technology will provide a *bridge to the future* by serving as a foundation for future exploration missions.
- *Designed with the crew in mind*, to include *safety in all phases of flight*
- The vehicle must be *able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

Methodology



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

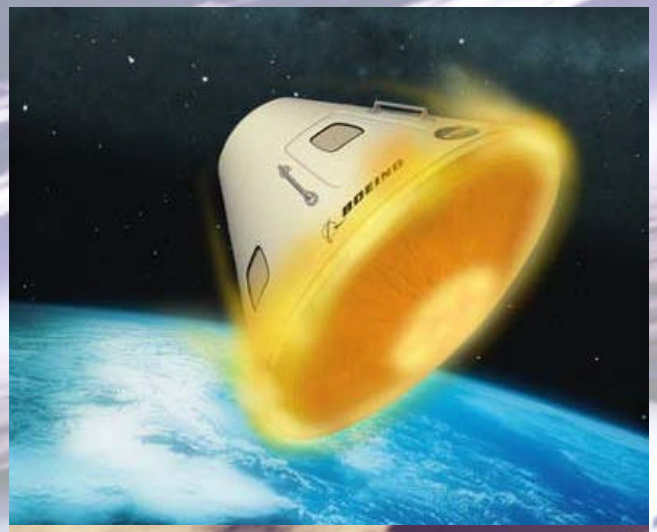
- One smaller, more advanced spacecraft
- Capable of light payloads
- Capable of transporting small crew
- Lift-body Design
- Advanced and experimental technologies

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

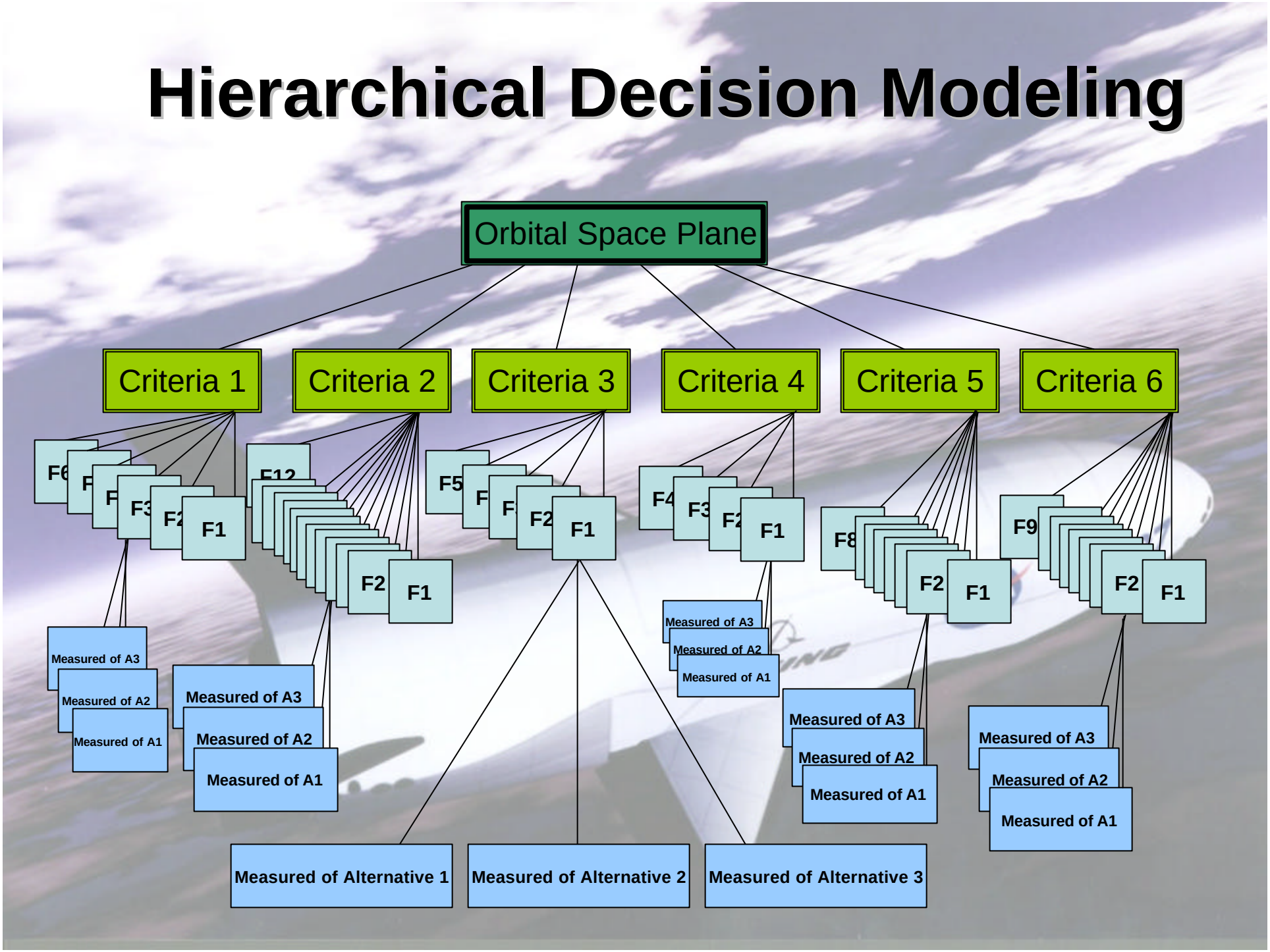
Factors: Subjective Judgment

- 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

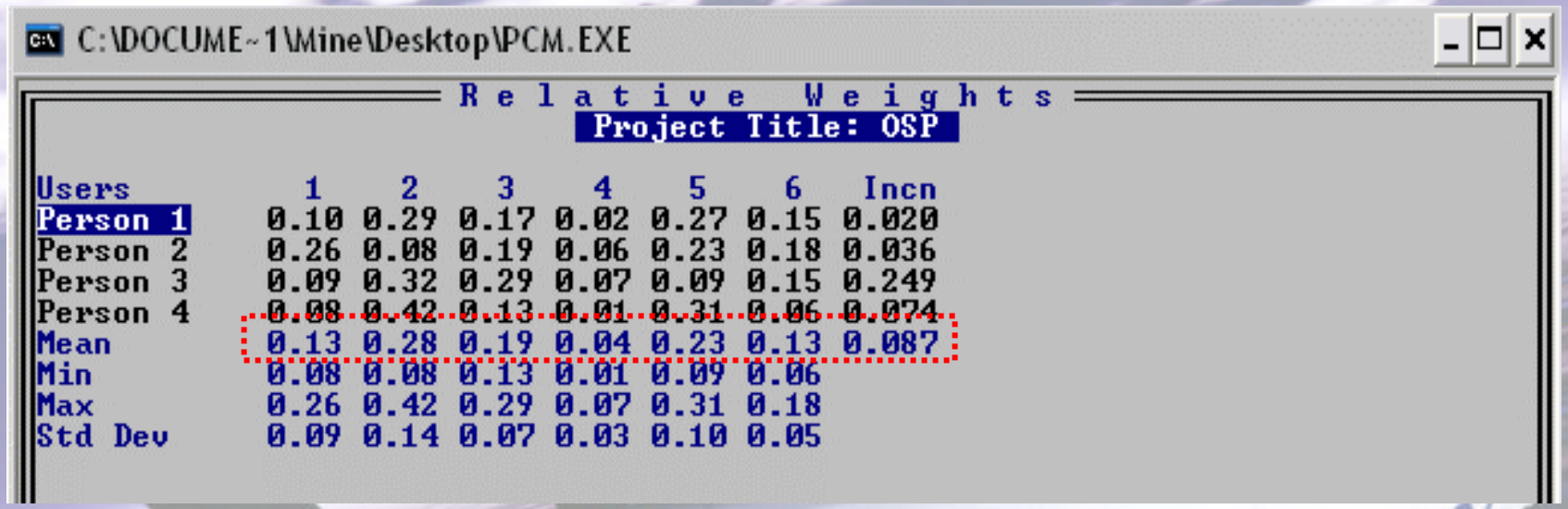


Alternative Evaluation

- 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



Users	1	2	3	4	5	6	Incn
Person 1	0.10	0.29	0.17	0.02	0.27	0.15	0.020
Person 2	0.26	0.08	0.19	0.06	0.23	0.18	0.036
Person 3	0.09	0.32	0.29	0.07	0.09	0.15	0.249
Person 4	0.08	0.42	0.13	0.01	0.31	0.06	0.074
Mean	0.13	0.28	0.19	0.04	0.23	0.13	0.087
Min	0.08	0.08	0.13	0.01	0.09	0.06	
Max	0.26	0.42	0.29	0.07	0.31	0.18	
Std Dev	0.09	0.14	0.07	0.03	0.10	0.05	

$$\sum_{n=1}^{6} w_n = 1.0 \quad , w_n > 0$$

Criteria 1: The proposed spacecraft (s) must be full 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

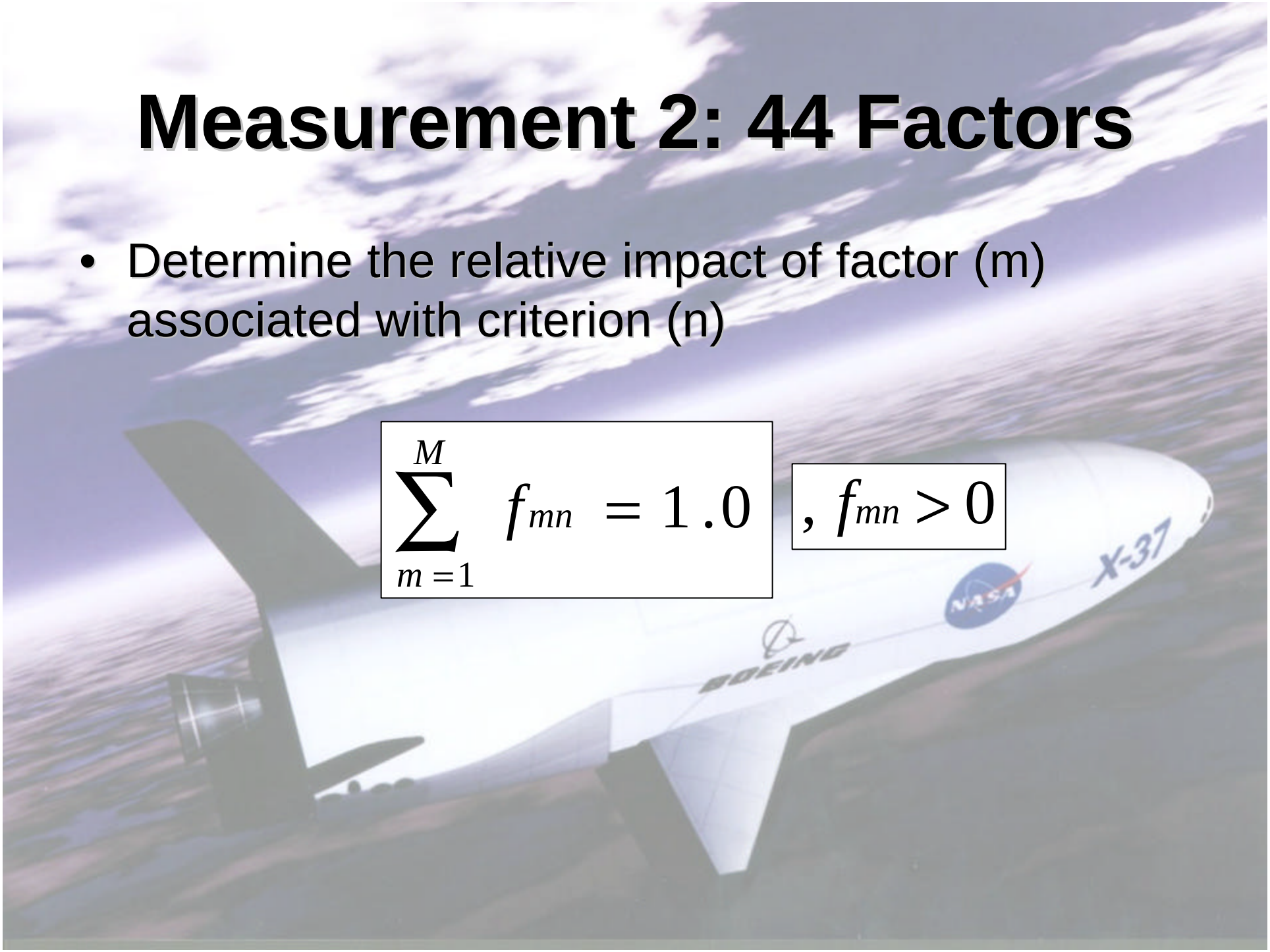
Criteria 5: Less cost to operate, launch and maintain than the Space Shuttle

Criteria 6: Capable of landing at a targeted site.

Measurement 2: 44 Factors

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

$$\sum_{m=1}^{M} f_{mn} = 1.0 \quad , f_{mn} > 0$$



Measurement 3: Performance and Physical Characteristics

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

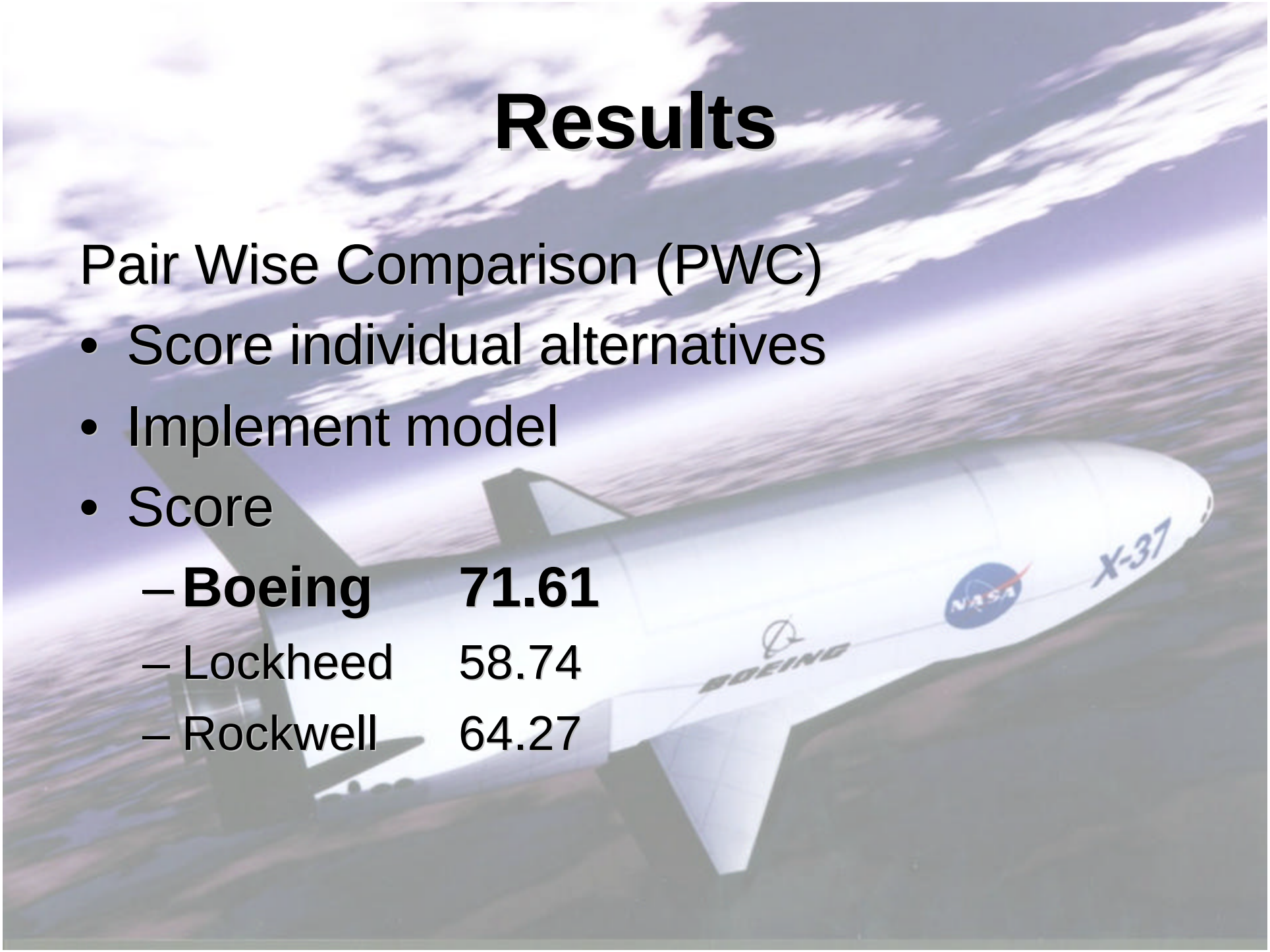
$$0 \leq U\left(v_{mn}\right) \leq 100$$

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 !


JETT
FERGUSON
TANNER
BURBANK
STEFANYSHYN-PIPER
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