The NOAA Satellite Observing System Architecture (NSOSA) study has examined nearly 100 alternative weather satellite constellations, looking for the most cost-effective arrangement of instruments, satellite orbits, and sustainment policies. Examining the cost-effectiveness of possible future satellite constellations requires quantification of each constellation’s ability to provide a set of sensor capabilities that support mission functions. The effectiveness, or value, of each alternative satellite architecture depends on orbital assignments, instrument payloads, and launch frequency required to maintain given levels of constellation performance. A key complexity in the value assessment is uncertainty, we neither know the stakeholders preferences nor the alternative system’s performance with certainty. Key sources of uncertainty include priority of different observation types and performance estimation of different constellation types against value measures. This paper presents several methods to assess value uncertainty of the large number of constellation examined in the NSOSA study. These methods focus on value uncertainty related to stakeholder consensus, constellation performance scoring, and stakeholder preference. The methods include approaches to resolving the strong correlations that exist between constellations because of shared satellite configurations.

**Introduction**

- NSOSA study recommends the most cost-effective constellation-level architecture for U.S. weather satellites (2028 – 2050 epoch)
- Alternative architecture value (V) based on the Environmental Data Record (EDR) value model (EVM; Maier and Anthes 2018)
- Multi-Attribute Utility Theory (MAUT; Keeny and Raiffa 1993)
- EVM captures the tradable range of measurement performance over N objectives (44 in NSOSA)
- Each objective associated with measures of performance (MOPs) at three levels
  - Study Threshold (ST): < ST→ no value; failure
  - Expected (EP): Expectation of stakeholders
  - Maximum Effective (ME): > ME→ no added value
- Alternatives scored against these levels

**NSOSA Swing-Weight Generation**

- Leadership ranked objectives by ST-ME performance swing
- Confident in most/least important swings
- No arguments for many steps up/down rank list
- Much discussion for few steps up/down rank list

**Swing-Weight Uncertainty: Interchange**

- Alternative to random variation when desired rank swapping inadequate
- Useful for nonlinear swing-weight structure
- Baseline weights swapped up/down in rank based on draws from uniform distribution (30% swap probability)

**Sources of Uncertainty in Alternative Value**

- Inexact swing-weight elicitation
- Preferences unexpressed in any single swing-weight set
- Early performance estimates inform alternative scoring
- Effects of unconsidered issues not captured by EVM

**Swing-Weight Uncertainty: Random Variation**

- 10% & 20% variation applied to baseline weights using draws from uniform distribution
- Results in rank interchanges for swing weights that ideally mimic assignment process uncertainty
- 95% confidence intervals (CIs) built for each constellation alternative value score

**Swing-Weight Uncertainty Confidence Intervals**

- Non-overlapping CIs→ sig. performance differences
- Overlapping CIs→ interchangeable alternatives
- Interchanges occur less freely than overlap suggests due to correlations

**Efficient Frontier**

- Quantifying uncertainty for preferred alternatives allows for the identification alternatives significantly more valuable than others under consideration
- Assumptions leading to overly frequent rank-order swapping only lead to a small number of preference swaps; variation does not alter the relative positioning of alternatives in the context of the EF
- Combining scoring weight uncertainty differentiates architectural differences from process noise
- Altering swing-weights as stakeholder preference shift does not promote/demote alternative clusters
- NSOSA results robustly to uncertainty sources examined here

**Tables**

- Table 1: Measures of performance at three levels for “Regional Imaging” sample objective.
  - Swing weights (w) define the stakeholder priority of improving objective performance from ST to ME
  - Swing-weight elicitation is subjective in nature

**Figures**

- Figure 1: Baseline 20:1 (blue) and altered 3:1 (orange) swing-weight curves
- Figure 2: Swing-weight swapping under 30% interchange model
- Figure 3: Alternative preference order swapping under 20% weight variation
- Figure 4: Swing-weight swapping under 30% interchange model
- Figure 5: Alternative preference order swapping under 30% interchange model
- Figure 6: 95% confidence intervals for 10%/20% random swing and 30% interchange approach

**References**

- Maier, M.W., and Anthes, R., 2018: The ERM value model for the NSOSA study, 1st Annual Symposium on Next Generation Environmental Satellite Systems, Austin, TX: Air. Meteor. Soc., 03.01
- Maier, M.W., and Anthes, R., 2018: The ERM value model for the NSOSA study, 1st Annual Symposium on Next Generation Environmental Satellite Systems, Austin, TX: Air. Meteor. Soc., 03.01