Mission Operations Comparison Study

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Outline of Presentation

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- Mission Operations Complexity
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Mission Operations Comparison Study

- Mission operations are under continual pressure to reduce their costs, most of which are personnel
- Goal of this study was to compare flight operations among several analogous space missions, accounting for differences in mission objectives and constraints
  - Total Flight Operations Team (FOT) personnel taken as proxy for cost
  - FOT sizes and Mission Operations Risk are compared in relation to the mission’s complexity
  - Study quantified mission operating complexity
- Sponsor: Landsat Mission Management Office, U.S. Geological Survey (USGS)

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Mission Operations Comparison Study (Cont'd)

- It was estimated that missions in low earth orbit performing earth-observation missions would be the most appropriate for comparison purposes
- The missions used in the comparison cover the spectrum from research-oriented to operational missions :
  - Operational meteorological missions
  - Landsat
  - Earth environment research missions

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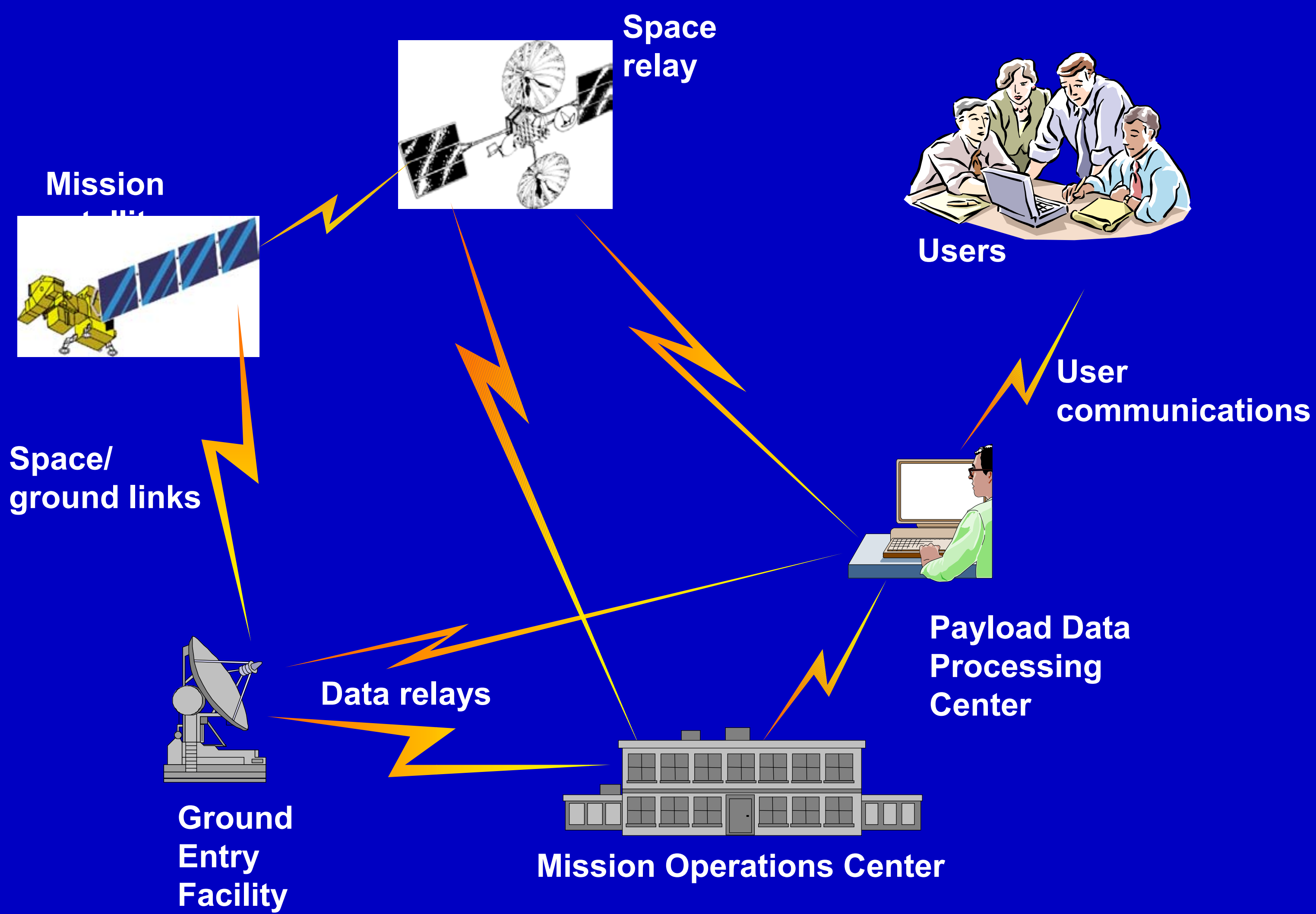
Illustration of Mission Operations



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Contact Support vs Offline Staffs

- Flight Operations Team staffs can be divided into two broad categories: Contact Support Operations and Offline Operations
- Contact Support Operations are concerned with the day-to-day operations of the mission:
  - Console operations, pass planning/scheduling, image acquisition planning/scheduling, ground station and space network utilization scheduling, command and ephemeris load generation, orbit determination, orbit maintenance

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Contact Support vs Offline Staffs (Cont'd)

- Offline Operations are concerned with activities for the longer-range operation of the mission:
  - Spacecraft sustaining engineering
    - Performance analysis, short/long term s/c activity planning, anomaly resolution, special operations planning, flight software maintenance, flight software equipment maintenance
  - Control Center Sustaining Engineering
    - Systems software and hardware maintenance, systems administration
  - Project Management/Administration
    - Project management, subcontract management, general administration, business administration, property management, configuration management

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Mission Operations Complexity

- The size of the Flight Operations Team (FOT) is driven by the complexity of mission operations
- Data thought to reflect various aspects of the complexity of a mission was collected
- A mathematical model was used to derive the overall complexity of operations for a given mission (i.e., a metric or factor), based on the data collected. It will be described in subsequent slides
- The premise of this study is that differences in mission staffing can be explained in terms of this complexity metric

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Mission Complexity Components

Components of Mission Operation Complexity	Rationale/Drivers
Instrument Payload Operating Complexity	Duty Cycle, Long-Term Acquisition Plan, Cloud Avoidance, On-board Data Recording vs. Overhead.
Number of Individual Instruments in Payload; Instrument Payload Weight	Multiply instruments in a payload will increase complexity.
Number of Satellites in the Constellation	Although some satellites and their payload are relatively simple individually, operation as a constellation will increase complexity.
Station-keeping Requirement	Meteorological Missions do not need station-keeping. Other missions need to maintain a precise ground track, or altitude.
Attitude Control Requirement	Usually automated but some missions require time-consuming periodic momentum dumping.
Scheduling and Deconfliction of Ground Assets	Complexity of this task is increased for missions with multiple downlinks.

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Mission Operations Risk & Mitigation

- Mission operations risk is defined in this study as the probability of instrument data loss, due to action of the Flight Operations Team
- Risk mitigation is defined as any action taken, personnel or material element added to decrease the probability of instrument payload data loss. It assumes nominal operation of the satellite and ground systems as a baseline
- Mission operations risk is intuitively reduced by adding personnel, but generally results in higher costs

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Risk-Mitigating Factors

Personnel and Material Resources	Risk Mitigation
Project Management (PM), Planning (Plg) and Sustaining Engineering (SE) Personnel Staffs	Typical PM, Plg and SE tasks involve analyzing trends in space and ground system components to identify potential problems early, and derive mitigating alternatives. They can also provide thorough verification of commands.
Contact Crew Size	Crew size can vary from 1 to 3. Operational missions will usually carry larger crew sizes to reduce chance for errors.
Shift Type	Some missions are staffed 24 x 7. Other missions are staffed 10 x 7, with unattended passes. Problems arising during unattended passes will take longer to identify.
Mission Operations Center (MOC)	Operational missions such as weather have a geographically-separated backup MOC.
Ground Entry Facility (GEF)	Space Network (SN) or other ground stations scheduled to provide backup.
Backup Hardware Strings at MOC and GEFs	A backup string can save a pass in the event of failure in the primary string.
Backup Communications Links	Reduce the risk of unavailability of instrument data at processing facility.
On-orbit Reserve/Backup Satellites	Reduce the risk of data unavailability due loss of satellite.

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Outline of Complexity Methodology

- The complexity methodology has been found appropriate to use for sparse data sets, as opposed to multivariable regression
- It is described in *Algorithmic Description of an Analytic Complexity Methodology*, by D. A. Bearden, O. F. Blackshire, and P. H. Young, Proceedings of the 24th Annual Conference of the International Society of Parametric Analysts (ISPA), San Diego, California, May 21-24 2002 (Reference 1)
- It was derived as a general complexity analysis tool which was first used to model the *development complexity* of a new program in the context of the "*faster, better cheaper*" concept.
- Outline of methodology
  - Select a dependent variable or "attribute"
    - FOT size, Offline Staff size and Mission Operations Risk
  - Select an initial set of independent attributes judged to be drivers for the dependent attribute

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Initial Set of Mission Complexity Independent Attributes

1.	Number of Satellites	1 to 5
2.	Effective Number of Satellites	1 to 4
3.	Shift Requirement (e.g. 24x7, 10x7)	70 to 168
4.	Contact Crew Size	1 to 3
5.	Data Latency Requirements (hrs)	4 to 48
6.	Number of Communication Downlinks	1 to 5
7.	Reference Daily Data Volume (GB)	0.054 to 169
8.	Ratio of Contact to Offline Personnel	0.33 to 1.45
9.	Station-keeping required?	Yes-No
10.	Frequency of station-keeping (days)	20 – Infinity
11.	Nbr Passes per Day (Data)	2 to 8
12.	Nbr Passes per Day (Planning)	4 to 55
13.	Nbr of Instruments	1 to 7
14.	Instrument Operating Complexity	Medium (3) to Very High (10)
15.	Instrument Weight (kg)	From < 100 kg to > 1500 kg

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Outline of Complexity Methodology (Cont'd)

- Involves the following basic steps
  – Perform ordinal ranking of independent attributes across systems
  – Compute the complexity for each system as the average of its ordinal rankings
  – Perform a regression of the dependent attribute against the computed complexities of all systems
- Methodology is illustrated by example of mass storage system Cost-Estimating Relationship (CER)

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Illustration of Derivation of CER for a Simple System

System A

Cost =
Terabytes =
Access Time =

System B

Cost =
Terabytes =
Access Time =

•
•
•
•
•
•

System Y

Cost =
Terabytes =
Access Time =

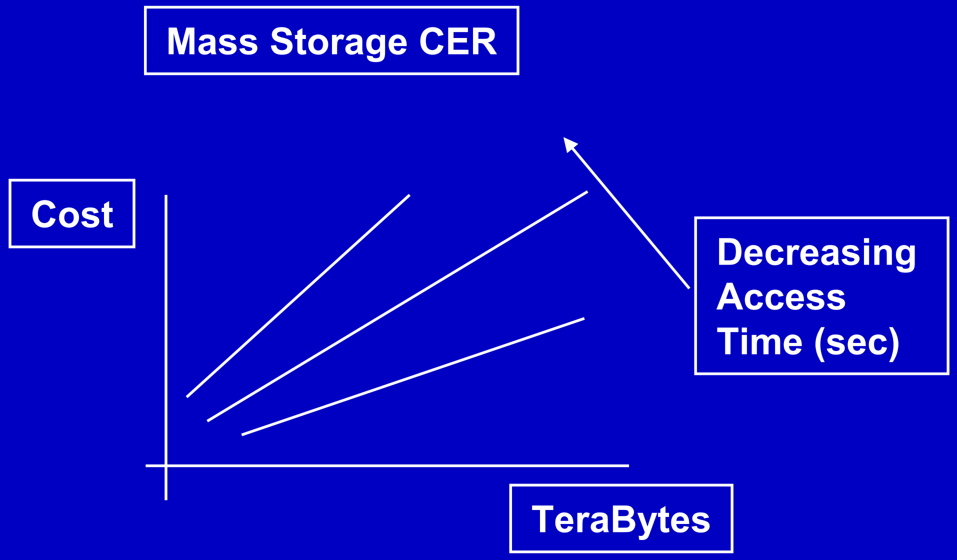

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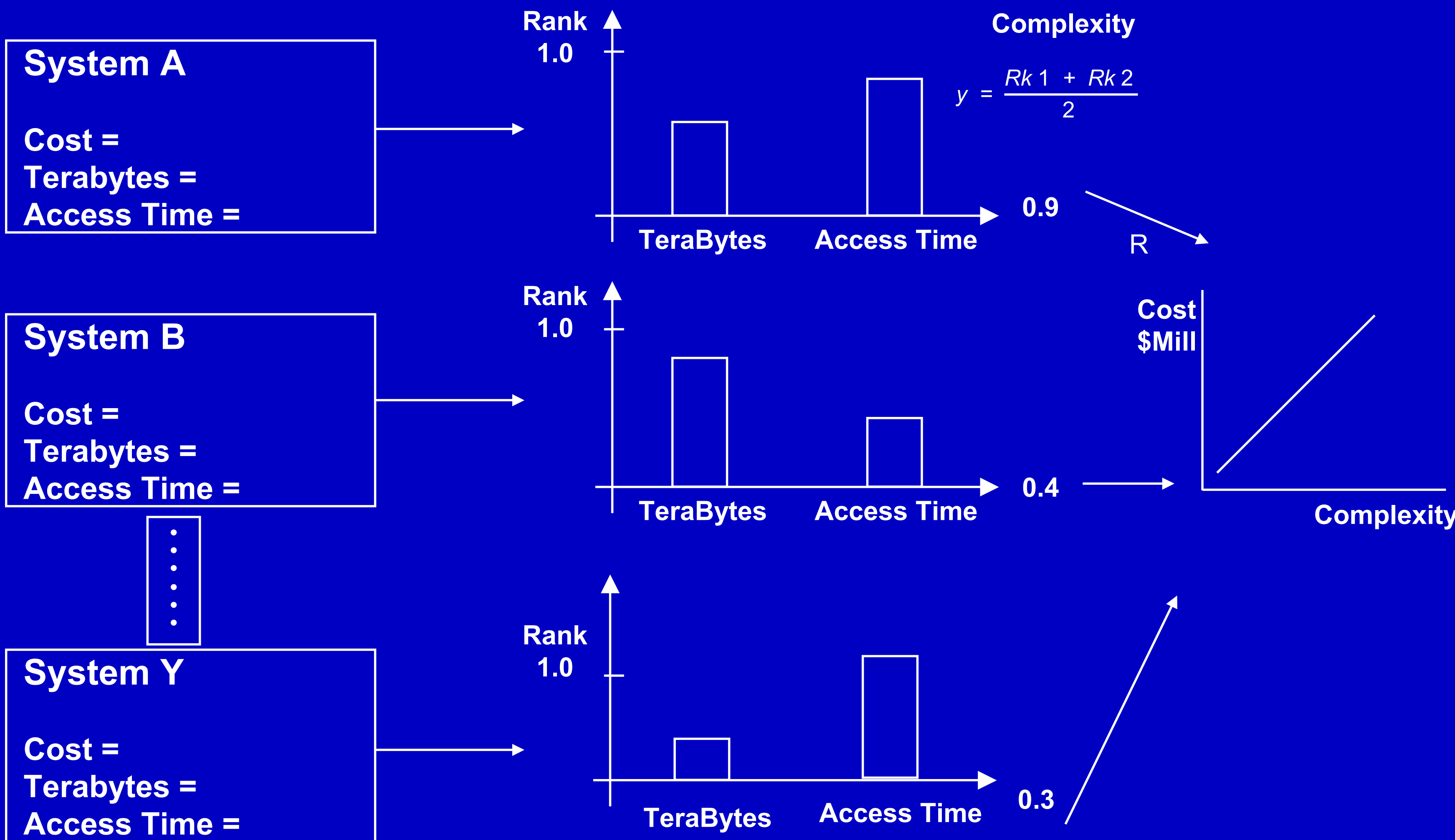
Illustration of Cost-Complexity Methodology for a Simple System



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More Details on Complexity Methodology

- For each independent attribute, calculate correlation coefficient r with respect to the dependent attribute
- Reject attributes between -.5 and +.5 as having little impact (these cut-off points are based on engineering judgment)
- Perform ordinal ranking of the selected independent attributes across the missions in terms of percentiles
- For each mission, average the percentiles across all its attributes. This is the calculated complexity factor with respect to this particular dependent attribute.
- Perform a linear regression and fit of the dependent attribute against the complexity factors of the missions in the data sample

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Complexity Calculation (FOT Size)

	Percentile Ranking of Attribute Across Missions, on Scale 0 to 1					
Mission	***No. Satellites***	***Contact Crew Size***	***Data Latency***	***No. Passes/ Day (Planning)***	***Instr. Operating Complex***	**Calculated Complex Factor 1**
A	0.000	0.666	0.167	0.666	1.000	0.500
B	0.000	0.166	0.167	0.166	0.333	0.166
C	0.833	0.666	1.000	1.000	0.666	0.833
D	0.833	0.666	1.000	0.833	0.666	0.800
E	0.000	0.166	0.667	0.500	0.000	0.267
F	0.000	0.166	0.667	0.333	0.333	0.300
G	0.000	0.000	0.667	0.000	0.000	0.133

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Illustration of Ranking

- **The following dataset is used as an example for the rankings obtained from Excel's Percentrank function**

Input Data	30	5	50	50	17	14.5	4
Value from Data set calculated by Excel's Percentage Rank Function	0.666	0.166	0.833	0.833	0.5	0.333	0

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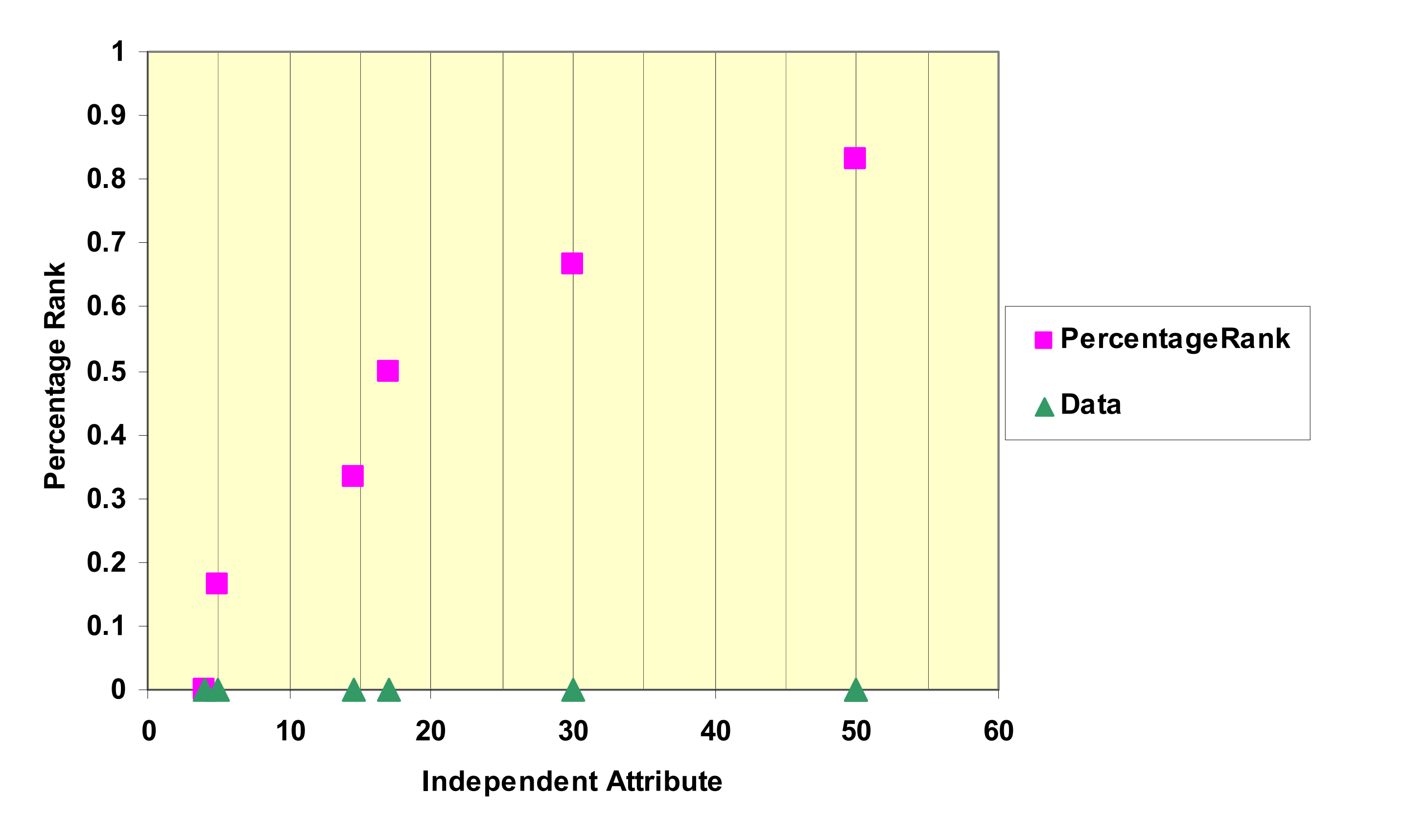
Illustration of Ranking (Cont'd)



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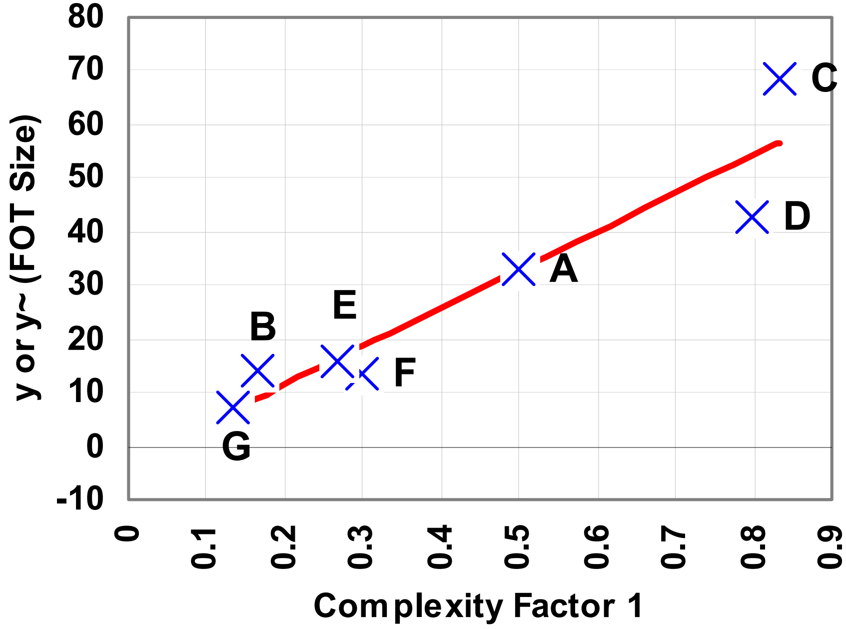
FOT Size vs Complexity Factor 1



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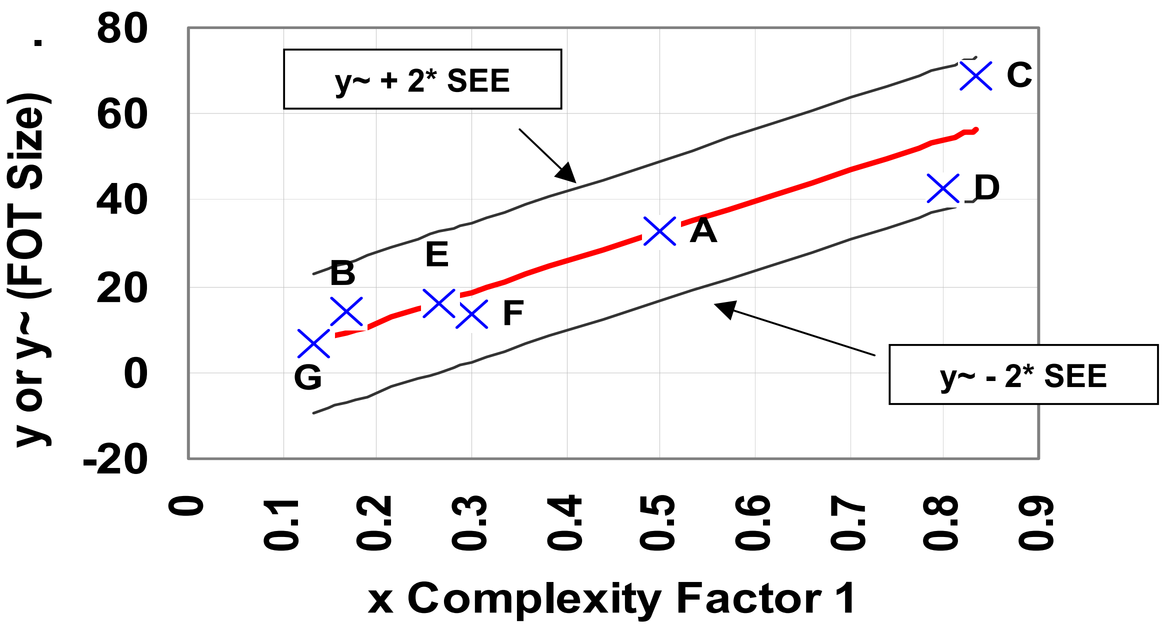
FOT Size vs Cplx Fact 1 with Confidence Intervals



SEE - Standard Error of Estimate

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Observations & Next Steps

- FOT size is well explained by the FOT Complexity factor - the estimate is well within two standard error of estimate (SEE) and thus is not an outlier.
- The SEE is an estimate of the standard deviation in the case of normally distributed data. The regression line is an estimate of the mean.

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Complexity Calculation (Offline Staff)

	Percentile Ranking of Attribute Across Missions, on Scale 0 to 1					
Mission	***No. Satellites***	***Contact Crew Size***	***Data Latency***	***No. Passes/ Day (Planning)***	***Instr. Operating Complex***	**Calculated Complex Factor 2**
A	0.000	0.666	0.167	0.666	1.000	0.500
B	0.000	0.166	0.167	0.166	0.333	0.166
C	0.833	0.666	0.667	1.000	0.666	0.766
D	0.833	0.666	0.667	0.833	0.666	0.733
E	0.000	0.166	0.667	0.500	0.000	0.267
F	0.000	0.166	1	0.333	0.333	0.366
G	0.000	0.000	1	0.000	0.000	0.200

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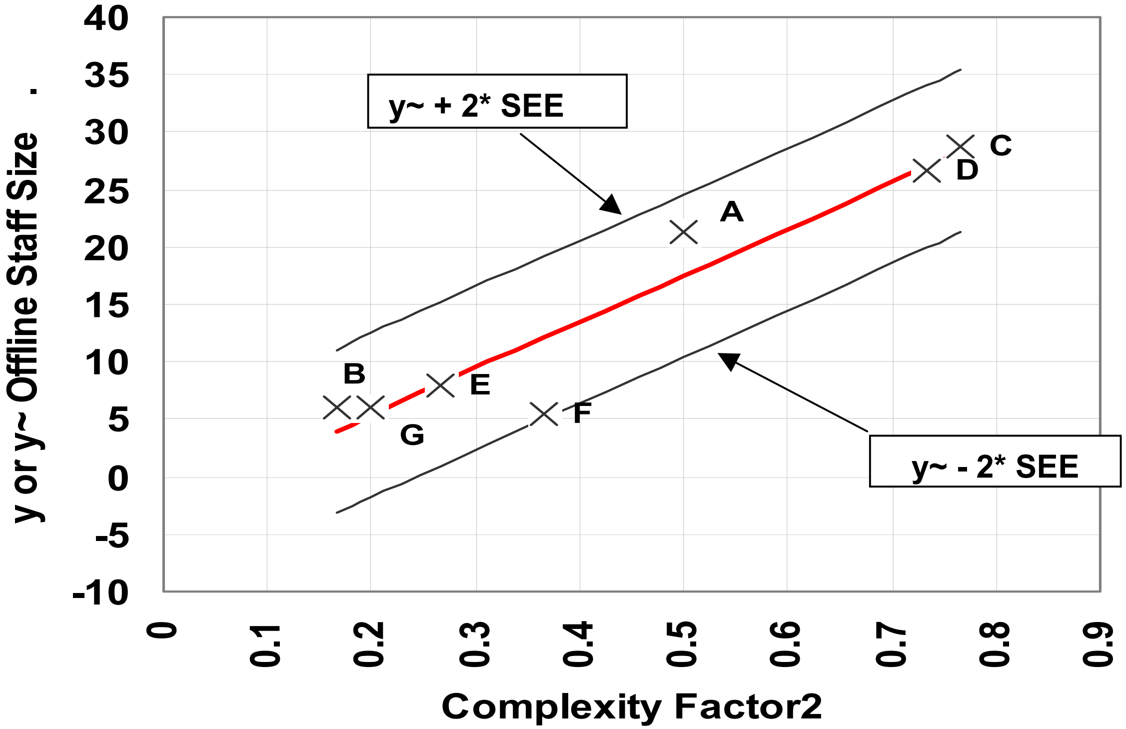
Offline Staff vs Cplx Fact 2 with Confidence Intervals



SEE - Standard Error of Estimate

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Mission Operations Risk-Reference Data

- In the absence of actual data, the study team assessed the operations risk level for all missions considered, based on engineering judgment. This assessment was quantified into the Mission Operations Risk reference data shown below

Mission	A	B	C	D	E	F	G
Mission Operations Risk	0.01	0.05	0.001	0.001	0.05	0.05	0.05

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Complexity Calculation (Msn Opns Risk)

	Percentile Ranking of Attribute Across Missions, on Scale 0 to 1				
Mission	***No. Satellites***	***Contact Crew Size***	***No. Passes/ Day (Planning)***	***Instr. Operating Complex.***	**Calculated Complex Factor 3**
A	1.000	0.334	0.334	0.000	0.417
B	1.000	0.834	0.834	0.667	0.834
C	0.167	0.334	0.000	0.334	0.209
D	0.167	0.334	0.167	0.334	0.251
E	1.000	0.834	0.500	1.000	0.834
F	1.000	0.834	0.667	0.667	0.792
G	1.000	1.000	1.000	1.000	1.000

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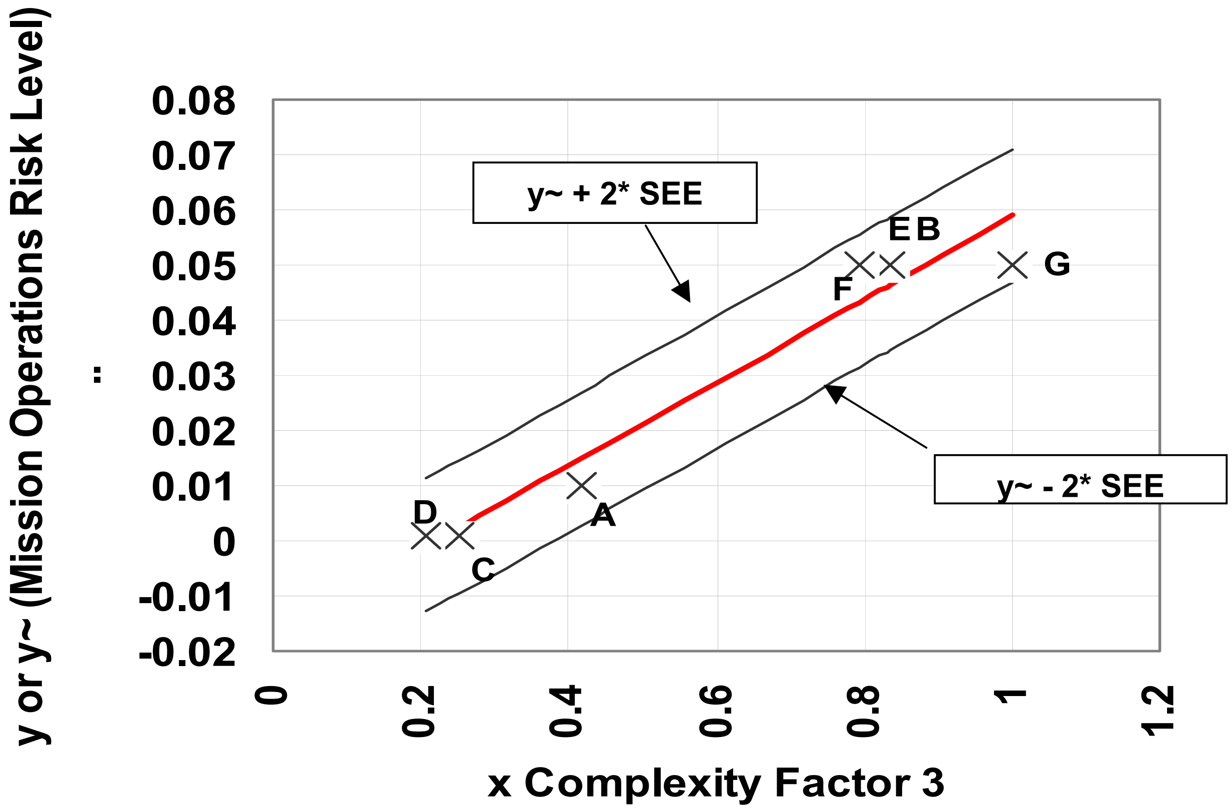
Msn Opns Risk vs Cplx Fact 3 with Confidence Intervals



SEE - Standard Error of Estimate

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Conclusions

- **In the three cases examined, all data points can be explained in terms of the data set in a statistically meaningful manner**
- **The formal definition of a Mission Operations Risk metric and additional historical data are necessary to produce a more definitive comparison between missions**
- **An example of a formal method to define this metric can be found in *Continuous Aerospace Risk Management and Assessment (CARMA): Process, Models, and Application in Space Systems Programs*, by S.B. Guarro, K.A. Feldman, and R. Dar, The Aerospace Corporation, presented at the 2002 Risk Management Symposium, McLean, Virginia**

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Remarks on Complexity Methodology

- As defined above, complexity relates ***ONLY*** to the dependent variable selected and its independent attributes. It should ***NOT*** be thought of as an intrinsic system property
- In general, the complexity factor for the FOT size will be different than that for the Offline Staff size and the Mission Operations Risk
- The exception is when identical independent attributes are selected for different dependent variables. This turned out to be the case for the FOT size and Offline Staff size

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