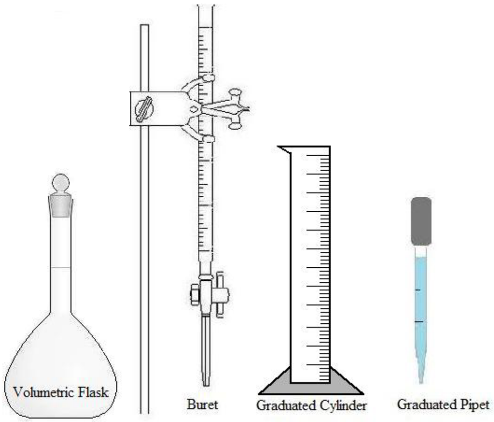
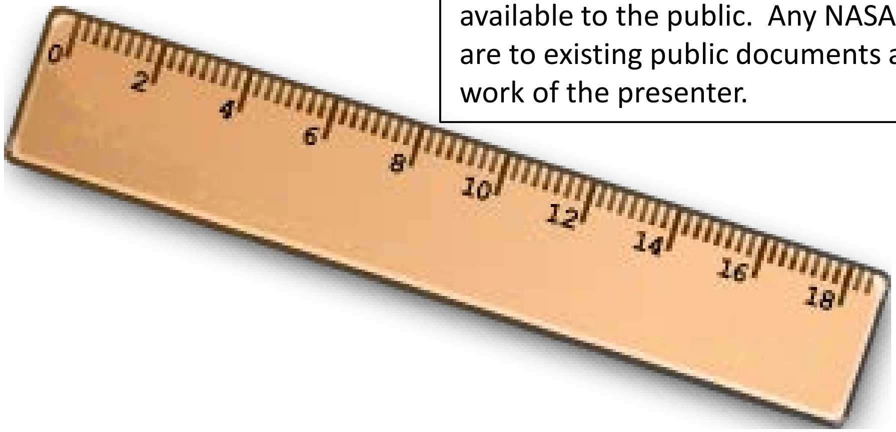
LIFE Systems - *Meeting Customer Needs*

Leading Indicators for Engineering of Systems





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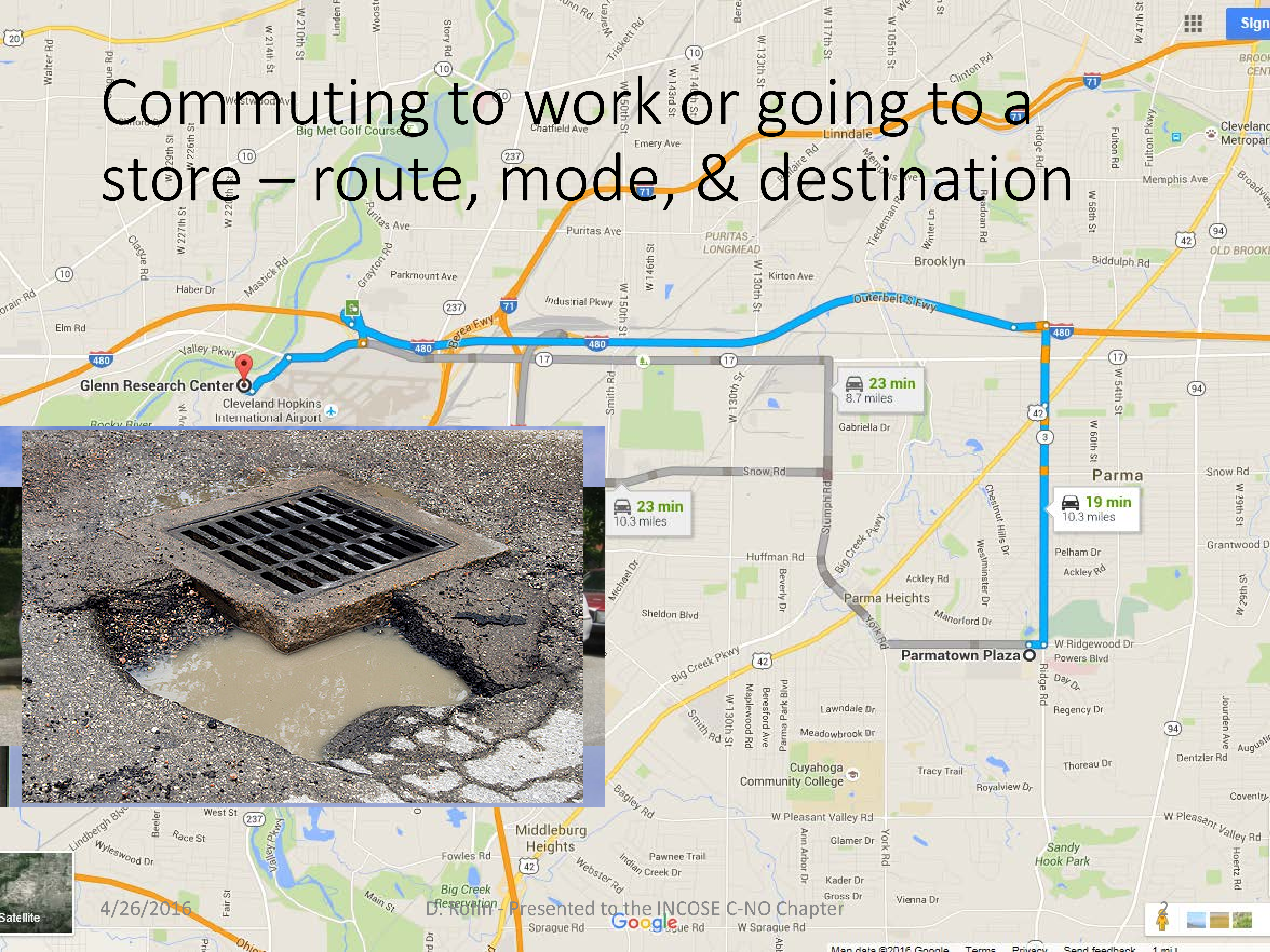
Commuting to work or going to a store – route, mode, & destination



Commuting to work or going to a store

- What would you do if something impacted the factors affecting your route, mode or final destination?
- What factors are the most important? Time? Cost? Knowing the store has a product?
  - A customer cares about how well a solution meets their needs – usually a balance of technical, cost and schedule
- Do the key factors include getting to the right place? How about the route/mode it took to get there?
  - Just like the right place, the end product has to be right
  - Just like the route/mode, the process for how to get there is important

Both product and process should be measured

A traffic jam…

How difficult is it to adjust your route…

- Once you are in a traffic jam?
- If you see it as you are ready to turn on to the on-ramp
- If you hear about it before leaving home on the radio or a smart-device?

Would you be willing to invest a few minutes to avoid a major traffic jam?

- Does it depend upon the risk?

Leading Indicators

- If you were in a car pool, what would it feel like if you arrive at someone's door and they call out to say they are not going to the office today?
- Wouldn’t you prefer to know about it ahead of time?
- Is it easier to change once there is a problem, or if you have some leading indicator?

The sooner you know, the easier to adjust and less the impact

So…

It is good to know:

- If the route/mode (process) you are taking will meet expectations
    - Spending a little time to evaluate the route/mode can save money, time, frustration in the long run
- If the final destination (product) will meet the needs
    - It is better to spend a little time than arrive at the wrong location

What is a Leading Indicator?

- A leading indicator is a measure for evaluating the effectiveness of a how a specific activity is applied on a project in a manner that provides information about impacts that are likely to affect the system performance objectives.
- A leading indicator may be an individual measure, or collection of measures and associated analysis that are predictive of future systems engineering performance before the system is fully realized.
- Systems engineering performance itself could be an indicator of future project execution and system performance.
- Leading indicators aid leadership in delivering value to customers and end users, while assisting in taking interventions and actions to avoid rework and wasted effort.

Source: Systems Engineering Leading Indicators Guide, Copyright © 2010 by Massachusetts Institute of Technology, INCOSE, and PSM

What is a Leading Indicator?

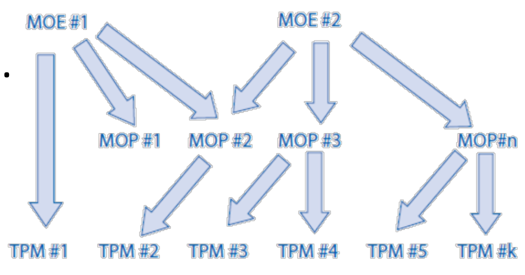
- They can predict the future, by measuring the past or present, and looking at trends or heuristics.

Types of Measures

- Product measures (e.g., mass and power)
  - Often MOEs, MOPs, TPMs, KPPs
- Process measures (e.g. verification and PRACA closures)
  - Can be used for project status, project process improvement, & institutional process improvement

MOEs/MOPs/TPMs

- MOEs are the "operational" measures of success that are closely related to the achievement of mission or operational objectives in the intended operational environment.
  - independent of any particular solution
  - a stakeholder expectation, by which they judge success
- MOPs are the measures that characterize physical or functional attributes relating to the system, e.g., engine Isp, max thrust, mass, and payload-to-orbit.
  - attributes important in achieving mission or operational success
  - measure of actual performance of a particular design solution
- TPMs are critical or key mission success or performance parameters that are monitored during implementation by comparing the current actual achievement of the parameters with the values that were anticipated for the current time and projected for future dates
  - typically selected from the defined set of MOEs and MOPs.
- Note: KPPs are not defined in the NASA SE Handbook



Source: NASA SP-2007-6105, NASA Systems Engineering Handbook

Choosing a car…

These are potential Measures of Effectiveness (MOEs)

These are potential Measures of Performance (MOPs)

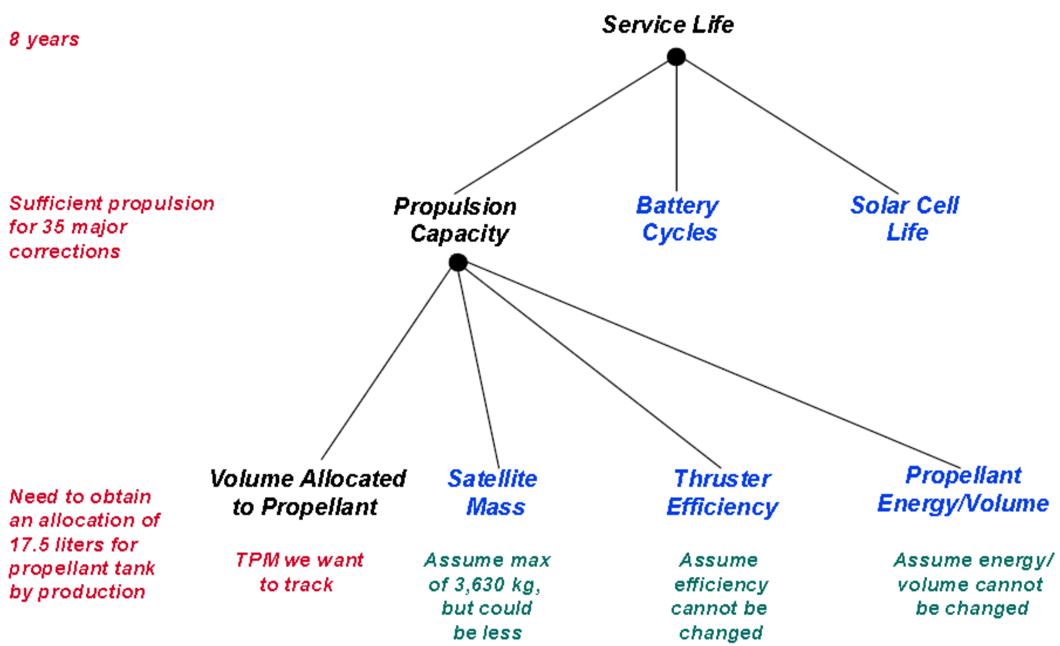
These are potential Key Performance Parameters (KPPs)

- What are some top… …hen choosing a car?
  - life cycle cost (hyb… vs. tr… …tional)? Comfort (sports car vs.
- …-cycle cost?
  - init… …purchase price, fuel efficiency, maintenance costs, res… value … LCC = *f*(ipp, fe, mc, rv)
- What drives fuel efficiency?
  - fuel to engine HP ratio, aerodynamics, weight, etc. …. FE = *f*(fehp, a, w)
- So when designing a system, you might want to track some of the critical Key Performance Parameters (KPPs) to make sure they are trending properly.

Example Product Measures

- As a simple example of how MOEs, MOPs, and TPMs work together:
  - An MOE may be that a data system is needed that does not fail when processing specific mission critical functions
  - The MOP could be the derived requirement that the system be able to provide uninterrupted computing for at least 100 hours (although usually there will be multiple MOPs)
  - The TPMs that are tracked may include fault tolerance, redundancy, and failure rate

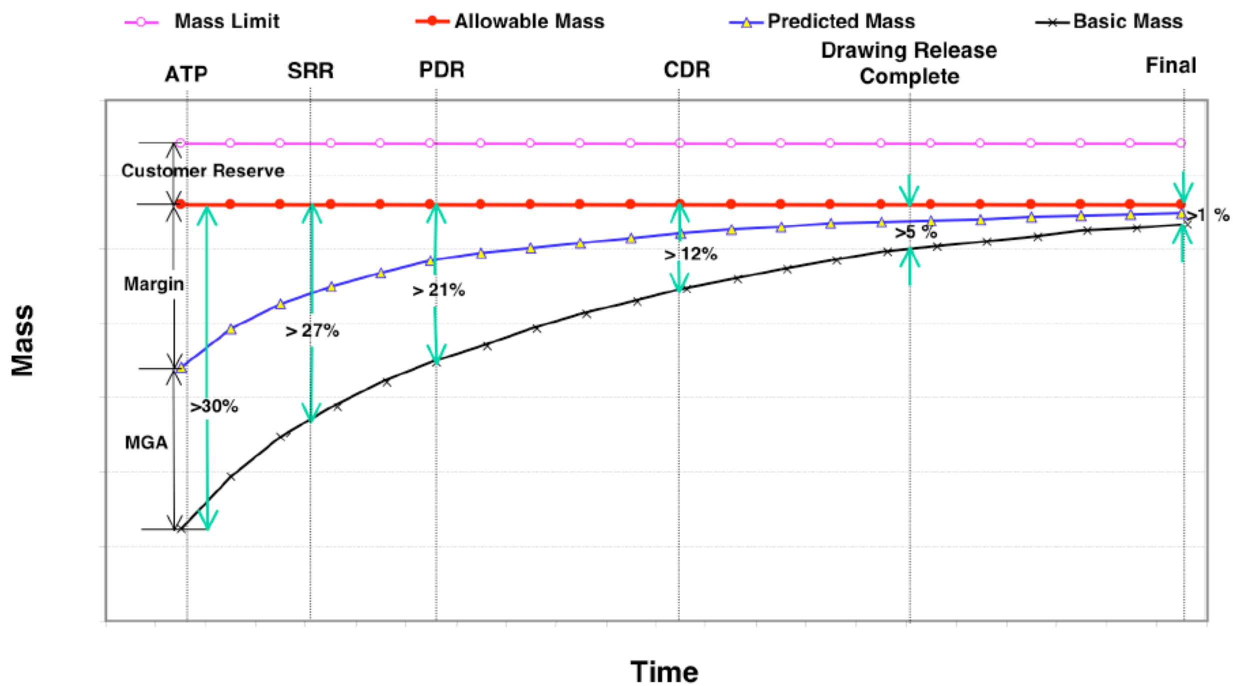
Spacecraft example



Type	Item	Threshold	Indicator
MOE/KPP	Service Life	At least 8 years	Service Life Expected - trend over time
MOP	Propulsion Capacity	At least 35 major corrections	Orbital Corrections Supported - trend over time
TPM	Volume Allocated to Propellant	At least 17.5 liters	Propellant Tank Capacity - trend over time

Source: INCOSE-TP-2003-020-01, Technical Measurement, Copyright © by PSM and INCOSE

AIAA Example TPM - Mass



Note: The Figure above represents the percentage of mass growth to the "Basic Dry Mass".

MGA + Margin % = [(MGA + Margin) / Basic Mass] x 100

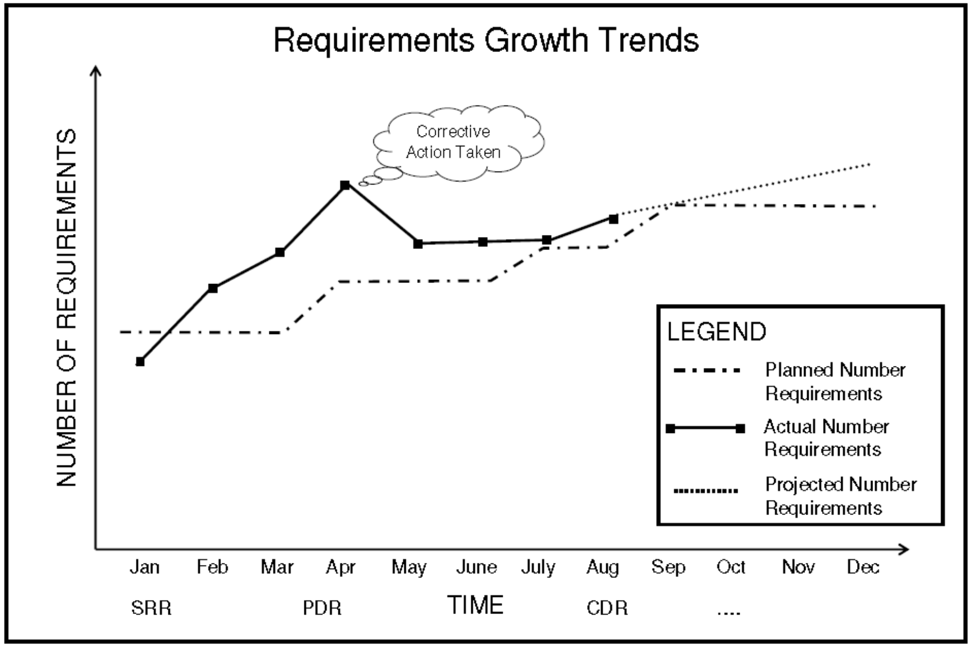
= [(Allowable Mass – Basic Mass) / Basic Mass] x 100

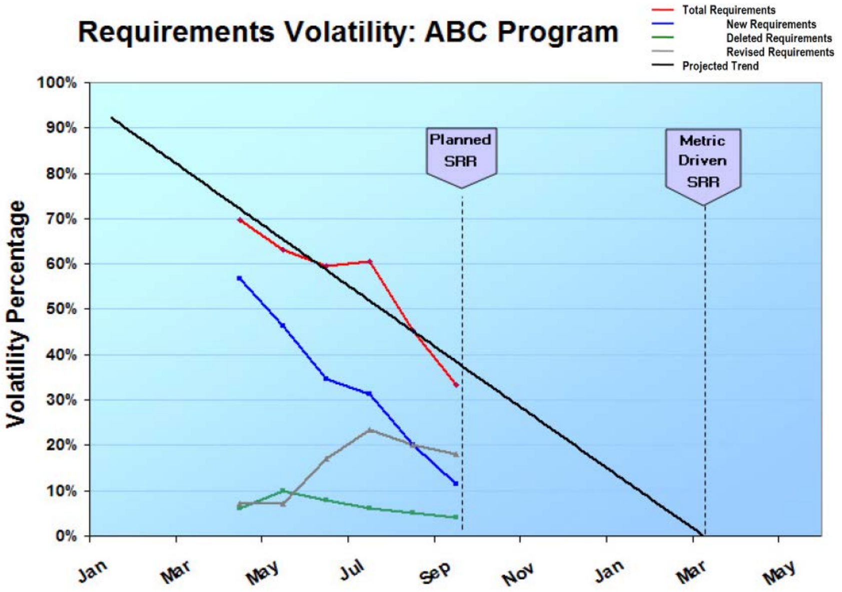
Figure 2 — Example Plot of Mass Versus Time

Source: AIAA S-120-2006 Mass Properties Control for Space Systems, © AIAA

INCOSE Process Leading Indicator Example - Requirements Trends

Rate of maturity of the system definition against the plan. Additionally, characterizes the stability and completeness of the system requirements that could potentially impact design, production, operational utility, or support.





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INCOSE Process Leading Indicator Example - Requirements Trends

3.1.1 Requirements Trend Specification

Requirements Trends	
Information Need Description	
Information Need	• Evaluate the stability and adequacy of the requirements to understand the risks to other activities towards providing required capability, on-time and within budget. • Understand the growth, change, completeness and correctness of the definition of the system requirements.
Information Category	1. Product size and stability – Functional Size and Stability 2. Also may relate to Product Quality and Process Performance (relative to effectiveness and efficiency of validation)
Measurable Concept and Leading Insight	
Measurable Concept	Is the SE effort driving towards stability in the System definition and size?
Leading Insight Provided	• Indicates whether the system definition is maturing as expected. • Indicates risks of change to and quality of architecture, design, implementation, verification, and validation. • Indicates schedule and cost risks. • Greater requirements growth, changes, or impacts than planned or lower closure rate of TBDs/TBRs than planned indicate these risks. • May indicate future need for different level or type of resources/skills. • Indicates potential lack of understanding of stakeholder requirements that may lead to operational or supportability deficiencies.
Base Measure Specification	
Base Measures	1. Requirements 2. Requirement TBDs/TBRs 3. Requirement Defects 4. Requirement Changes 5. Requirement Change Impact
Measurement Methods	1. Count the number of Requirements (record associated attributes of interest; e.g., Process Phases, Disposition Action, Maturity States, Priority Levels, Cause, Impact Level, Classification Type, and Dates & Times) 2. Count the number of Requirement TBDs/TBRs (record associated attributes of interest; e.g., Process Phases, Disposition Action, Maturity States, Priority Levels, Cause, Impact Level, Classification Type, and Dates & Times) 3. Count the number of Requirement Defects (record associated attributes of interest; e.g., Process Phases, Disposition Action, Maturity States, Priority Levels, Cause, Impact Level, Classification Type, and Dates & Times) 4. Count the number of Requirement Changes (record associated attributes of interest; e.g., Process Phases, Disposition Action, Maturity States, Priority Levels, Cause, Impact Level, Classification Type, and Dates & Times) 5. Estimate the impact of a Requirement Change

Each Example includes supporting information:

- Information Need Description/Category
- Measurable Concept and Leading Insight Provided
- Base Measure, Measurement Method, and Units
- Relevant Entities and Attributes
- Derived Measure and their Function
- Indicator Description, Sample, Thresholds and Outliers, Decision Criteria, and Indicator Interpretation
- Additional Information, including Related Processes, Assumptions, Additional Analysis Guidance, Implementation Considerations, Users of the Information, Data Collection Procedure, and Data Analysis Procedure

Source: Systems Engineering Leading Indicators Guide, Copyright © 2010 by Massachusetts Institute of Technology, INCOSE, and PSM

References

- Systems Engineering Leading Indicators Guide v2.0, Copyright © 2010 by Massachusetts Institute of Technology, INCOSE, and PSM
  - A list of potential indicators that can be utilized.
  - Summary table and then detail on each indicator.
  - Focuses on the process indicators, relegating the product measurement to one category.
- Systems Engineering Measurement Primer v1.0, Copyright © 1998 by INCOSE
  - Provides detail about how to go about implementing measurement in a generic sense.
- INCOSE-TP-2003-020-01, Technical Measurement v1.0, Copyright © by PSM and INCOSE
  - Focuses on product measurement.
  - Describes (including the relationship between) MOEs, MOPs, KPPs, and TPMs.
  - Describes how to implement them, but does not provide a list of potential product measurement metrics.
- NEW INCOSE-TP-2015-001-01, Project Manager's Guide to Systems Engineering Measurement for Project Success, Copyright © 2015 by INCOSE
  - Suggest how a PM might utilize SE measures to help manage a development
- NASA SP-2007-6105, NASA Systems Engineering Handbook Rev 1, December 2007
- ANSI/AIAA R-020A-1999 Recommended Practice for Mass Properties Control for Satellites, Missiles, and Launch Vehicles, © AIAA
- AIAA S-120-2006 (Standard) Mass Properties Control for Space Systems, © AIAA
- AIAA S–122-2007, Electrical Power Systems for Unmanned Spacecraft, © AIAA

Lesson Learned/Guidance

- TPMs can be useless, unless the trend is monitored (do not just report today's status)
- Need a minimal set that is *meaningful and actionable*, i.e. something management will actually act upon.
- Measuring the wrong thing can make matters worse
- Personal observations:
  - A lot of things can be measured; make sure you are measuring the right thing
  - Too many metrics can be overwhelming
  - Manual tracking can require a lot of resources

Discussion