Software Support for Improving Technology Infusion

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TBD: KenJ’s picture to go here
Technology Infusion Impediments

New mission concepts enabled by new technologies (autonomy, agents, ...), but...

Infusion of advanced technologies problematic:

- Requirements-related: Miscommunicated, misunderstood or under-defined customer (mission) requirements
- Readiness-related: Technology deemed non-flightworthy (unforeseen unresolved engineering issues)
- Competitiveness-related: Near-equivalent technologies are or will become available

Needs:

- Clearer definition of mission requirements
- Early identification of technology-specific engineering difficulties
- Ability to decide among architectures, technologies
- Projected status of competing technologies

Challenges:

- Multi-disciplinary nature:
  No individual expert in all areas; No individual can juggle all details at once
- Groundbreaking nature of new mission concepts and autonomies:
  Past experience provides only a partial guide
- Resource constrained:
  Many risks that, if untamed, lead to abandonment or wasted resources
- Need good decisions early:
  Early on, lack information (e.g., detailed design) on which to base decisions

Note: these all apply to many areas, not just space!
Expertise + Process + Software

Human Expertise

Information gathering and decision making done by relevant subject area experts

TIMA

Technology Infusion Maturity Assessment

Risk-Based Process

Stakeholders → Requirements → Risks

Mitigations → Costs

Selection → Documentation

Software Support

Information repository, Calculations, Visualizations, Decision Support
TIMA process: Risk-based Roadmapping

**What do you want?**

"Objectives"
"Requirements"
"Goals"

**What can get in the way?**

"Risks"
"Failure Modes"
"Defects"

**What can you do about it?**

"Mitigations"
"Solution Options"
"Preventions, Analyses, Controls, Tests – PACTs"

Mick Jagger (Rolling Stones):
"You can’t always get what you want"

Descoping – strategic abandonment of objectives.
Reprioritize objectives; primary, secondary...
Determine attainment if given additional resources ($, mass, ...)

Dr. Michael Greenfield (NASA HQ):
"Risk as a resource"
Trade risk for other resources.
Use risk as an intermediary between other resources.
Issues outside of technologist expertise.
Issues unique to flight development.

Matt Landano (JPL):
"Do the right thing & do it right"
Can’t afford all possible mitigations, so must choose judiciously.
Know the purpose(s) of each mitigation.
Day 1 – day of the pessimists!

Objectives – what you want
Risks* – what could occur to detract from attaining objectives
Impact (Objective x Risk) - proportion of the Objective lost if Risk occurs

* All risks, including those whose mitigation is planned:
  Makes available for scrutiny explicit assertions of risk reduction
  Allows risk and its mitigation to be involved in trades
  Reveals dependencies on mitigations (what if can’t do it on time?)

Day 2 – day of the optimists!

Mitigations – what could be done to reduce risk
Effect (Mitigation x Risk) – proportion by which Mitigation reduces Risk

Day 3 – day of the realists!

Select – Mitigations to perform
  Objectives to discard
  Resources to ask for

Decision-making guided by accumulated information

Getting the right people is key!!!
Mission scientists, technologists, relevant disciplines’ engineers, assembly/integration, testing, QA, operation, programatics
Software Necessary!!!

Typical DDP information set:
50 objectives, 31 risks, 58 mitigations

DDP process and *custom software* enables models of this scale to be *built* and *used* effectively.
Flexible Process Support

Sets of information needed for the TIMA process

- Status info
- Nominal TIMA process flow
- Choice of visualization
- Export TIMA information
- Decision making assistance
- Notes to track TBDs, progress, etc
Straightforward conceptual data

**TREES** of Objectives, Risks & Mitigations

**RELATIONSHIPS (LINKS)** between Objectives & Risks ("Impacts") and between Mitigations and Risks ("Effects")

**ATTRIBUTES** for the details, e.g., title (string), value (number/string), description (text), ...

*Upward-compatible extensions over time (e.g., “time phase” of Mitigations)*

*Calculations fast for now, scale-up becoming an issue*
TREES, MATRICES, BAR CHARTS

Multiple views:
- Uniform color conventions
- "Focus" to draw attention, span leap view to view
- Views kept in correspondence
Custom Visualizations: risk chart

Risk = impact \times likelihood

"Isorisk" boundary lines!

The axes are log scale

When you've got numbers, make use of them!
Custom Visualizations:

“stem-and-leaf” for sparse matrix

Dilemma: inevitably more information than can readily fit onto one screen...

Objectives

Impacts of Risks on Objective

Extends work of JPLers Howard & Hartsough
Custom Visualizations:
scroll bar is bar chart in miniature!

Visible portion of the bar chart

Left portion of out-of-view bar chart
Slider, showing the visible portion of the bar chart
Right portion of out-of-view bar chart

Inspired by Edward Tufte!
58 Mitigations, each an independent choice
$2^{58}$ (approx $10^{18}$) ways of choosing!

**Heuristic search:**
- Simulated Annealing – included in DDP tool
- Genetic Algorithms – included in Java prototype
- Machine Learning – successful experiments
Cost-Benefit trade space insights

58 mitigations = \(2^{58}\) (approx \(10^{18}\)) ways of selecting.
Simulated Annealing used to search for near-optimal selections.

Significant improvement possible; excellent case for more funding!

Sweet spot!
Region of diminishing returns

Risk basis for calculations: risk detracts from attainment of benefits; mitigation of risk costs resources.
CONCLUDING SUMMARY

- **Information:** make most use of information available early in lifecycle
  - Combine knowledge from experts and past experience
  - Accommodate both evidence and estimates

- **Process:** gather the right information the right way
  - Objectives, including their relative importance
  - Risks, and by how much they impact objectives and requirements
  - Mitigations, and by how much their use would reduce risk

- **Tool support:** effectively handle voluminous amounts of information
  - Capture experts’ knowledge on-the-fly during intensive sessions
  - Present information through cogent visualizations
  - Derive additional knowledge via calculation and search

- **NET RESULT:** Utilizable Products:
  - Specific collection of tasks, purposeful, costed, scheduled
  - A traceable rationale, quantitative scoring, reviewable
  - Risk-based understanding, thorough, calibrated

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