Understanding the Technical Rationale and Intent of Requirements

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Agenda

- **Objective of Intent Aware Requirements (IAR)**
- **The Problem**
  - Describe the Problem
  - The Tool-Trap
- **The Proposed Solution**
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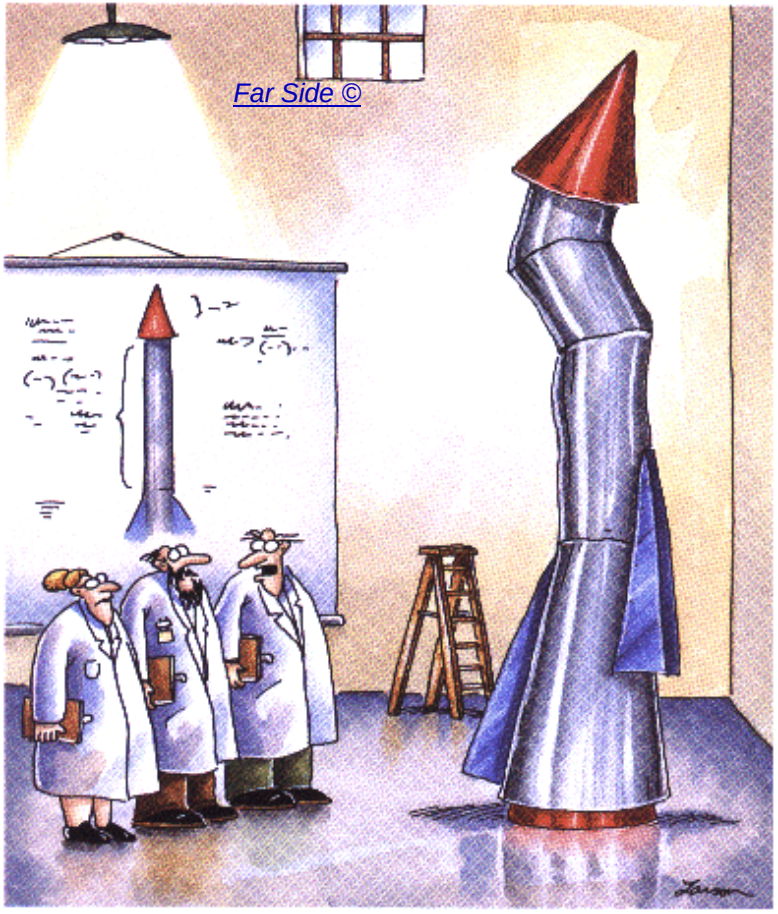
  - The IAR Solution
    - Intent Defined
    - IAR Goals
    - Functional View
    - Guidelines for Implementation
- **Summary**

Objective

The Objective of Intent Aware Requirements (IAR):

- Helps the Program Office (the Customer) Develop an Accurate and More Complete Set of Requirements
- Helps the Contractor to Better Understand the Rationale, Justification, and Customer's Intent Behind each Requirement
- Better up-front Understanding Results in a Better Chance at Obtaining a Validated Design Solution, Delivered in Less Time and at Reduced Costs



"…but it meets all the requirements in my tool.'

The Problem

- **System Engineers too Often must Make Critical Design Decisions without an Adequate Understanding of the Basis of the Requirements**
  - The missing information typically are the technical rationale and customer intent behind system level requirements
  - Consequences:
    - Costly requirements instability
    - Increased failures and delays during development
    - Failed validation

- **Current Processes are not using Requirements Management Tools to Adequately Capture this Missing Information**
  - Systems Engineers practice robot-like elimination of important details about the requirement in the drive to write small, succinct and discrete requirements
  - Some customers may purposely hold back the details with a “Do as I say and don’t ask why” point of view

Example

- For example, consider the following requirement, which is one of many for an aerospace launch vehicle program

AB001: Flight performance data shall be transmitted in real time to support range safety and flight test functions.

- In this hypothetical case the requirement was written by the program office customer and contractually provided to the contractor

Different Meanings are Possible

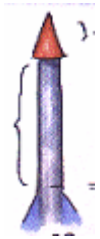
	Interpretation	Cost/ Schedule	Sub-Systems
1	All captured flight data will be sent to the ground station in real time	$20M/ 24 Months	Comm, GNC, Science
2	Only flight dynamics data to be provided in real time. All flight test data will be sent to the ground station within 10 minutes.	$15M/ 18 Months	Comm, Science, Recorder
3	Only safety critical flight dynamics data to be provided in real time.	$5M/ 4 Months	Comm, GNC, recorder
4	Safety critical flight dynamics data to be provided, as available.	$2M/ 6 Months	Comm, GNC

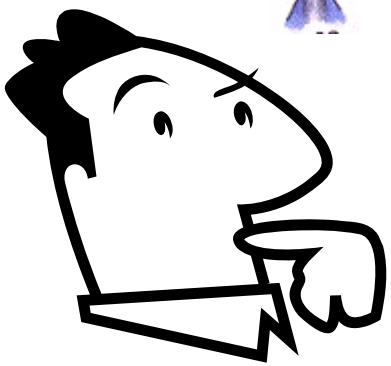
All Values are notional
GNC = Guidance Navigation and Control

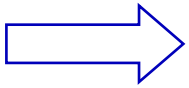
Tool - Trap

- **Requirement Management Tools Provide an Excellent Means for Requirements Traceability, Functional Allocation, Metrics, and Configuration Control of the Baseline**
- **However, the Engineers use of Short Database Entries, as Opposed to Detailed Text, Fails to Adequately Capture the Rationale or Customer Intent**

Customer's Intent







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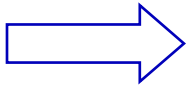
Requirements as Documented in a Database



Implementation

The Solution

- Before Tools, We Captured Requirements in Big, Thick, Multi-Volume Documents
- Contained much of the Detail Now Missing from Tool Based Requirements Management
  - However, was labor Intensive to Perform Traces, Look-ups, Functional Allocation, and Change Management
- Some Organizations are Now Augmenting the Database Tools by Adding Meta-Data or Text Attributes to Capture Rationale
  - SPARTA Inc. has overseen implementation of this approach for the Missile Defense Agency's Targets and Countermeasures program
  - Good short term solution, but still doesn't address intent, and no intelligent software to perform analysis on that additional text attribute

Short Term Solution

- **Tools, such as DOORS®, CORE® and Requisite Pro®, Simply use a Database (e.g., Access, Oracle) that Capture Text Data which has been Hand-Entered, Imported, or Pasted-in**

- **Attributes can be Defined by Defaults or by the Tool's Administrator and are Associated with each Requirement**
  - Some commonly used attributes include source, priority, target release, responsible designer, cost, risk, department, platform, options, and reason for change

- **A Simple Method for using Existing Tools to Better Aid the Requirements Analysis is to Add an Attribute called "Rationale"**
  - This attribute would be a text field used to manually capture the owner's rationale and the intent behind the source requirement

  - The "Rationale" attribute must get updated over time as the requirements analyst becomes more aware of the customer's intent, and as the customer becomes more capable of conveying the intended outcome

The IAR Solution

- **The Proposed, Long Term, Technical Solution Introduces Intent Aware Requirements (IARs) into Requirements Management Processes and Tools**

- **So What is an IAR?**
  - A Requirements Management Concept that puts the Focus on the Customer's Intent and Includes the Essential Rationale Necessary to Completely Understand both the Single Requirement and the System as a Whole

-So what is intent?

Intent Defined

- **As Defined by the PhD's:**
  - Intentions are relationships between cognitive states and their object or objects [Haugeland 97]
  - Intentions facilitate the transformation of cognitive processes from cognitive realities into a physical one [Howard 01]
  - Intentions act as an automaton that organizes unconscious processes into a hierarch of basic conscious components [Clemen 96]
  - Intentions can be viewed as emergent products of competitive physical interactions [Gibbs 01]
  - The external theory of intention awareness argues that interaction not only reveals patterns of actions and intentions, but also creates intentions and patterns of intentions [Howard 02]

Too Complex. Need to Make Assumptions and Reduce Scope in Order to Produce an Intelligent Software Solution.

Intent Defined

- **As Defined by the Commanders:**
  - The commander's intent describes the desired endstate
  - It is a concise statement of the purpose of the operation and must be understood two levels below the level of the issuing commander
  - It must clearly state the purpose of the mission
  - It is the single unifying focus for all subordinate elements
  - It is not a summary of the concept of the operation
  - Its purpose is to focus subordinates on what has to be accomplished in order to achieve success, even when the plan and concept no longer apply, and to discipline their efforts toward that end

Source: FM 100-5 (Washington, DC: GPO, 1993, 6-6

Intent vs. Rationale in Terms or IAR

- **Technical Rationale – the "Why" in Severe Detail**
  - A reasoned technical argument made to justify a course of action or decision
- **Intent – The Planning and Desire to Perform an Action**
  - Includes technical rationale, plus other influencing factors:
  - Cost, schedule, risk, goals, abilities, and commitments
- **Initial Intent – The Customer May not Always be Successful Document Their Intent**
  - Initial Intent can sometimes be Derived from the Rationale
  - Intent evolves over time, as it is continually derived and/or pried out of the customer's mind

Common Elements Needed to Capture Technical Rationale

Element	Description
Journalistic Questions	What, Why, When, Who
Assumptions	Assumptions are acceptable if the actual knowledge is still being developed, however all assumptions must be disclosed.
Constraints	What are the known limitations and constraints.
Background	Not all engineers on the program have the same level of knowledge about, or familiarity with, the history or background behind some the project's requirements. Furthermore, the fact that engineers come and go on the project exacerbates this need.
Cited references	This is the source of the source. If a source requirement uses parameters that came from other sources, then those sources should also be disclosed.
Source of performance parameters	Any value that is listed (e.g., 100 ms) should have a link to its origin (trade study, historical data, engineering judgment, assumption). Experience shows that figures are inevitably challenged, if not during the requirement reviews then certainly at some point after a test fails to meet its required performance parameter.
Desired effect	Purpose/goal. State the requirement in such a way to ensure that the intended result of the action will be understood.
Definitions	Define all unique terms (such as real time and near real time). Some terms may seem obvious, but can be easily taken out of context if not clearly defined.

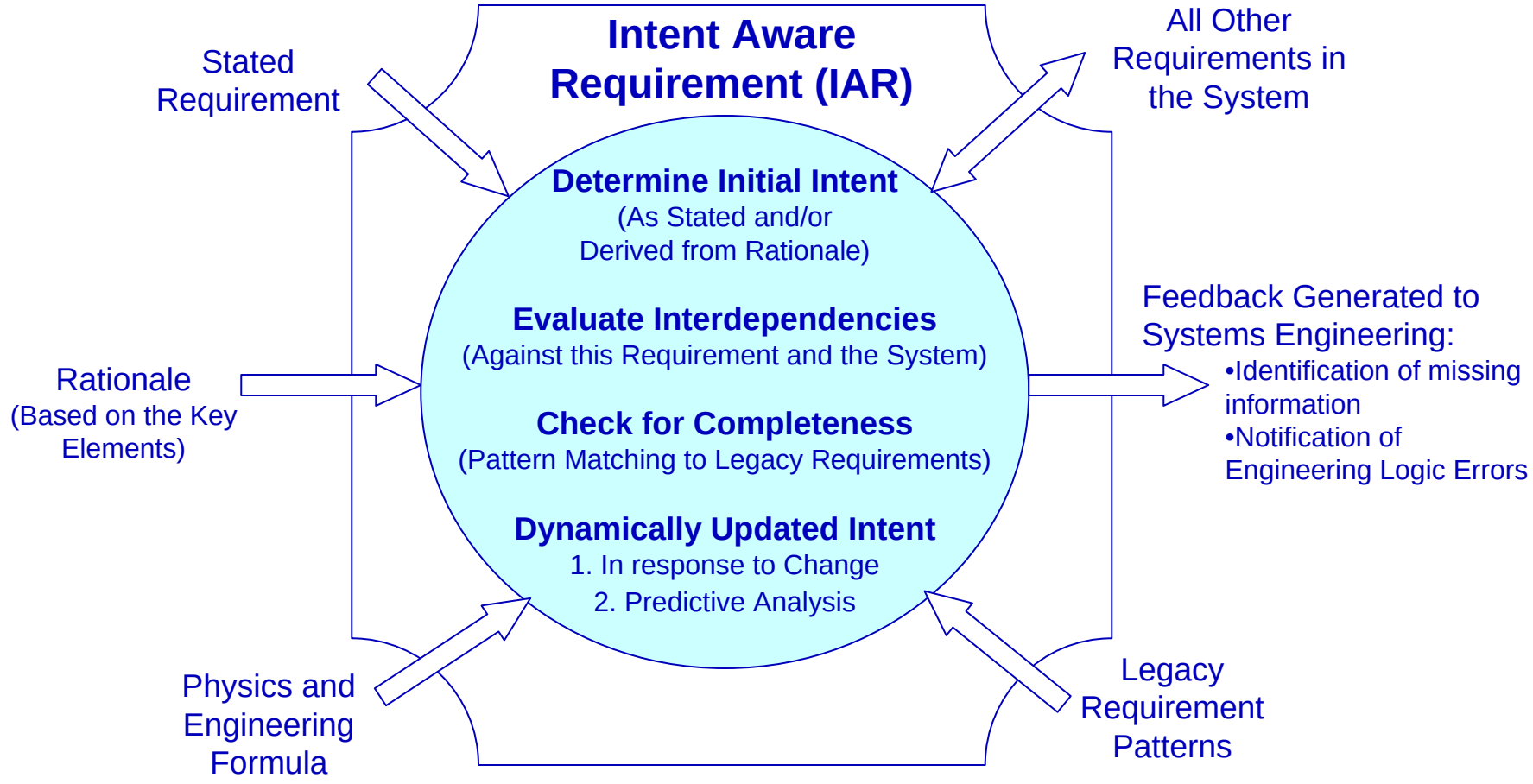
Can't Possibly Fit all of This Into a Single "shall" Statement.

IAR Goals
(Application of IAR Concept)

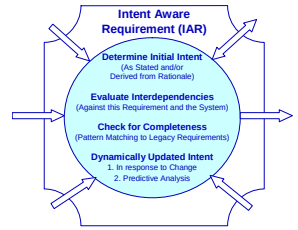
- Capture the Details of the Requirement's Rationale and the Customer's Underlying Intentions
- Derive Intent from Rationale and Other Inputs
- Facilitate Predictive Analysis of the Implications to the System Caused by the Dynamic Interrelationships Among Multiple Requirements
- Check Requirements and Rationale for Completeness
- System Wide Correlation of Intent
- Dynamically Respond to Changes in Intent
- Monitor Lower Level Design to Assure Consistency with the System Level Intent

Overall - Helps our Defense Systems to Effectively Satisfy Mission Area and Capability Requirements

IAR Functions, Inputs, Outputs



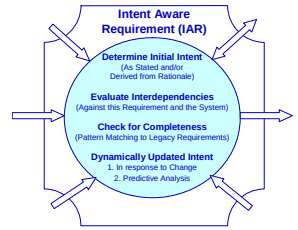
IAR Functions



1. **Determination of Initial Intent:**
   - Derives the initial intent from the stated requirement and given rationale
   - Rationale and the stated requirement are inputs
     - Full rationale may not be completely known at the start of a project
   - Establishes the starting point for building more awareness and for tracking changes

2. **Evaluate Interdependencies:**
   - Interdependencies between other requirements in the system
   - Interrelationships with external factors
   - Determine how a new or changed requirement would affect other requirements or intent in the system
     - The change may cause one of these other requirements to now violate an engineering principle or no longer meet the stated or derived intent.
     - Need for an effects-based approach

IAR Functions



3. **Check for Completeness:**
   - The stated requirement and current rational is compared against a store of related requirements from other programs in the same technical domain
   - Technical accuracy is evaluated
   - Gaps can then be identified and brought to the attention of the systems engineers / customer for resolution

4. **Dynamically Updated Intent:**
   - A change in the owner's intent may change the traced requirements and many of the other system requirements and intentions
   - This function must react based on the prior establishment of interdependencies
   - This function must also evolve the initial intent towards an actual intent (*the "ideal reasoner*")

IAR Functions

*"The ideal reasoner would, when he had once been shown a **single fact in all its bearings**, deduce from it not only all the chain of events which led up to it but also all the results which would follow from it."*

- Sir Arthur Conan Doyle

- By Capturing the Requirements with all their Rationale and Intent in Tools, Systems Engineers Can then Utilize those Tools to Pay Off throughout the Entire Product Development Life Cycle
- Next Step is to Develop Such an Application to Assume the Role of the "Ideal Reasoner"
  - Therefore the following guidelines are being proposed to aid in the development of such a tool, or add-on module to an existing tool
  - These are Guidelines and not the Implementation

Guidelines for Implementing IARs

1. **The IAR Functions Must Work Together and Share Information**
   - Changes in intent, identified by one process, need to get propagated to the other functions and then evaluated as a system.
   - Operator is notified when intervention is needed

2. **Must be Supported by Intelligent Software Techniques**
   - Adaptive machine learning needed to enable the IAR functions to formulate intent based on the stated requirements and rationale
   - Predictive analysis needed to anticipate user needs and provide relevant data that a customer may not seek explicitly

Guidelines for Implementing IARs

3. **Address Data Manipulation**
   - IARs desire for verbose rationale creates a formidable environment for information overload
   - Context-Aware Agents could be used to proactively search and retrieve data for analysis
     - Could also use Natural language Processing (NLP) or Probabilistic latent Semantic Analysis techniques to analyze and process the text

4. **Address Data Fusion**
   - Identify patterns based on inputs (stated requirement and rationale)
     - Autonomously identify the missing elements to then be presented to the analyst for further review

Guidelines for Implementing IARs

5. Address Data Correlation

- Performed within the tool to allow the evaluation of interdependencies between all other requirements in the system
  - Examine the use of spectral analysis or term vectors
- The resultant correlation of requirements, rationale, and intent establishes a multitude of associations and provides the basis for performing dynamic updates to intent

6. Must Not Effectively Increase Workload or Schedule

- The amount of data generated and number of iterations in intent has to be realistically kept in check
- There is a project dependant limit to how much intent needs to be described to achieve a common understanding and to make the concept demonstrably useful
- Contractual and legal considerations must be taken into account before implementation, since IARs add a considerable amount of detail to the original stated requirement

Summary

- Through the implementation of IARs into Existing Processes and Tools, System Engineers at both the Program Office and Contractor Levels can Gain a more Complete Understanding of Requirements and can then Communicate them more Fully and Accurately to the Designers and to Developers of Lower Level Specifications.

- IARs will Equip System Engineers to Perform the Analytical Work Necessary to Translate an Operational Need into a Design Solution.

- Furthermore, Incorporating IARs will Reduce Program Costs by:
  - Adding stability to requirements
  - Reducing failures and delays
  - Achieving successful product validation with higher assurance

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