Developing a Test Data Requirements Matrix (TDRM)

This section addresses the process for refining the test program issues; the development of sub-issues that result from a decomposition of the issue statements; developing JT&E evaluation criteria; development of measures: Mission Level Measures, Measures of Effectiveness, Measures of Performance; identification and specification of applicable data elements, and how these support the development of appropriate test scenarios and data collection procedures. The culmination of the dendritic analysis process is the completion of the Test Data Requirements Matrix which will also form the basis for developing the PTP and the individual detailed test plans that are necessary for ensuring a coherent, well planned, and executed test event. The analyst must not lose sight of the objective of the JT&E: collect data that is relevant to the stated test issues for the calculation of the measures that will be used in the evaluation analysis. The TDRM development process provides the rigor for conducting a defensible JT&E program.

Test Data Requirements Matrix

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Module Info

- Module owner: Chuck Walters, 703-681-4024, charles.walters@osd.mil
- Date of last update: 24 October 2003
- Dendritic analysis provides decision tool that breaks down JT&E problem statement and principle issues into smaller components to determine venues, scenarios, test resources, and CRE costs to execute JT&E
  - Includes process for developing JT&E problem statement and issues
  - provides procedures for developing measures of effectiveness and measures of performance to include their supporting data requirements

Purpose

- Provide new Joint test planning projects and Chartered JT&E teams with sufficient background in process for developing Test Data Requirements Matrix
- Explain process for development and refinement of JT&E problem statement and supporting test issues.
- Explain rationale and concept for development of test measures (MOE & MOP) that lead to identification of data that must be generated in the JT&E test events.
- Provide means to trace data requirements to test scenarios and instrumentation requirements
- Provide ability to conduct and complete Consolidated Resource Estimate for proposed JT&E

Overview

- Integrated Data Requirements List
- Problem statement
- Issues and sub-issues
- Test Criteria
- Test measures
- Data elements
- Scenarios
- Constraints on IDRL
- Summary

Integrated Data Requirements List

- List of data requirements linked to JT&E problem statement, issues that must be answered by the JT&E, and test measures (MOEs & MOPs)
- Ties data requirements to test resources required to generate and collect the data (test participants and their operational equipment, data collection instrumentation)
- Supports development of operationally realistic test scenarios
- Identifies JT&E test articles (what is to be evaluated) e.g Joint TTPs, process, architecture, methodology
- Supports development of Consolidated Resource Estimate (CRE)

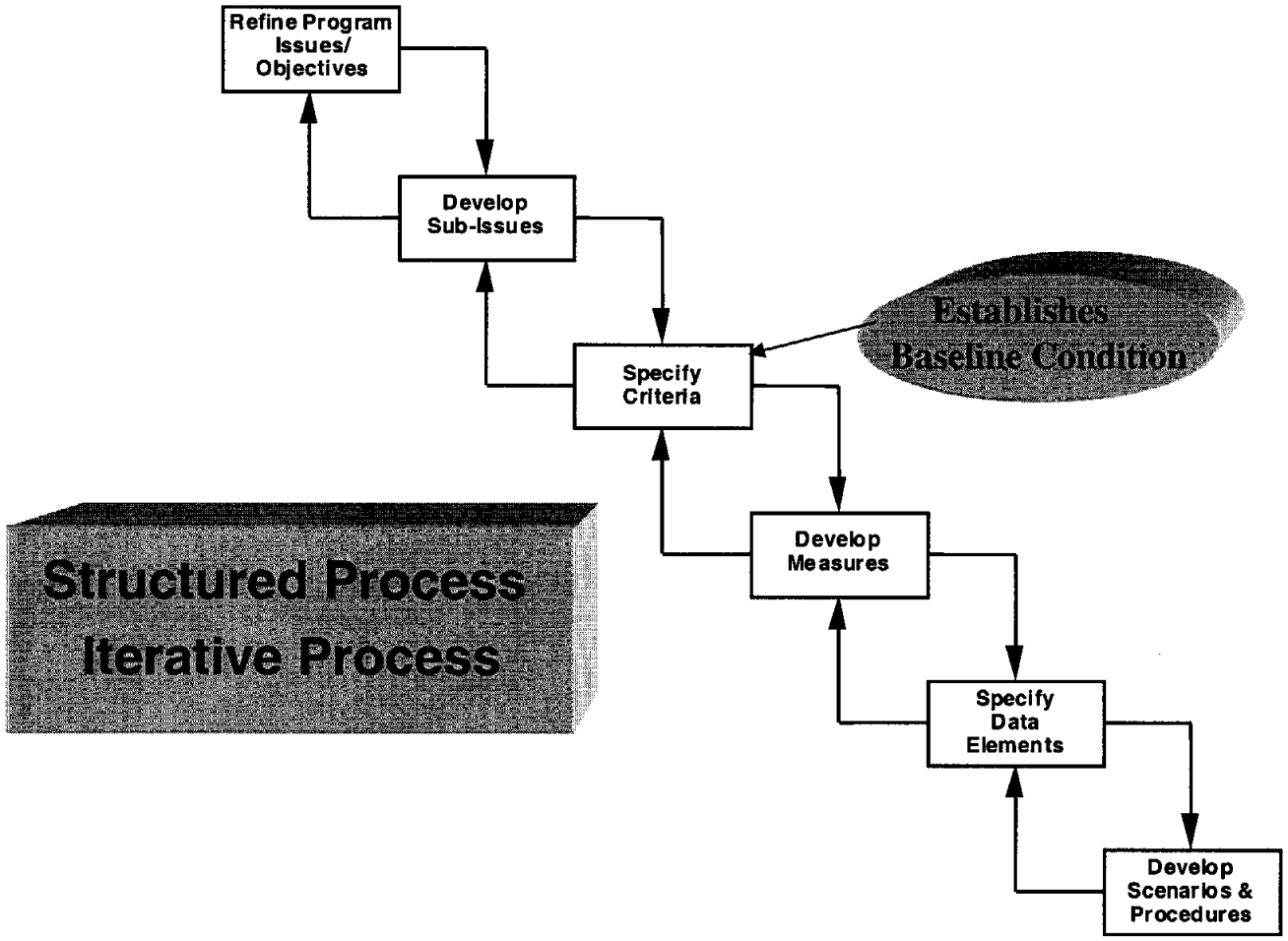
Goal: IDRL Matrix

Issues/ Objectives	Sub-Issues	Criteria	Measures	Data Elements	Scenarios	Instrument-ation	Data Source
1.0	1.1	1.1.1	1.1.1.1	1.1.1.1	1.0	1.1	Op Plans
	1.2	1.2.1	1.2.1.1	1.2.1.1		1.2	Questionn
				1.2.1.2	2.0	2.1	
			1.2.1.2	1.2.2.1		2.2	TSPI HUD Tape
				1.2.2.2			
2.0	2.1	2.1.1	2.1.1.1	2.1.1.1	3.0	3.1	
	2.2	2.2.1	2.2.1.1	2.2.1.1		3.2	
			2.2.1.2	2.2.2.1	4.0	4.1	
				2.2.2.2		4.2	
				2.2.2.3			

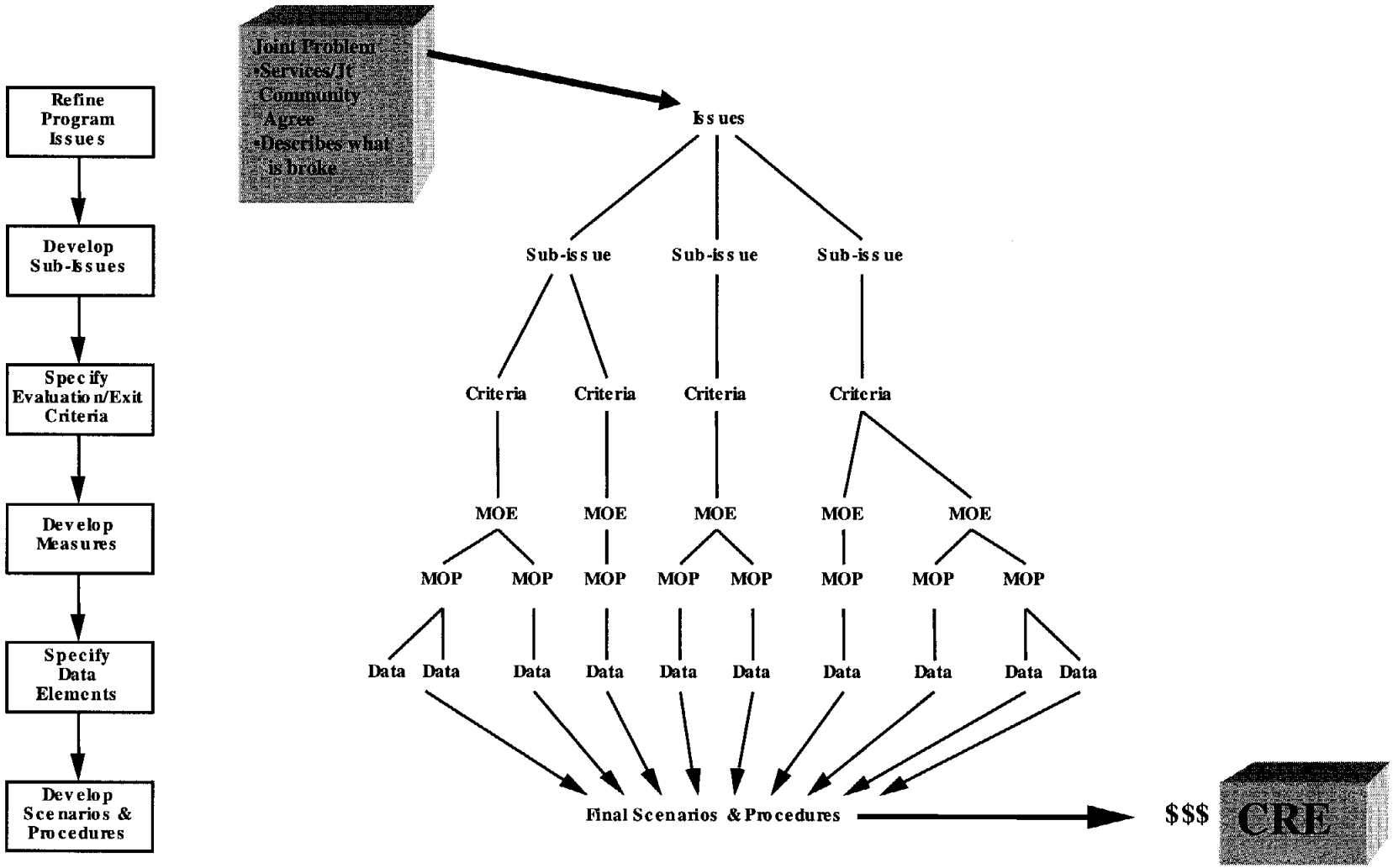
(why) ← → (what)

(who, when, where, & how)

IDRL Matrix Development Process



IDRL Matrix Development: Dendritic Analysis Structure



Decision Analysis Methods

Decision Analysis - Purpose

- Achieve consensus from group of subject matter experts and JT&E Project team
  - Means to identify and validate most relevant factors that led to Problem Statement and principle issues
  - Identify and prioritize parameters that caused problem
  - Isolate most likely operational thread parameters that lead to potential improvements in capability
  - Facilitate and maintain control of meetings intended to obtain specific pre-determined products
  - Others where human interactions require logicial approach to obtain useful, meaningful perspectives that lead to problem solution or information relevant to discussion topic
  - Minimize personal bias and prevent stovepiping

Decision Analysis Methods

- Delphi Technique
  - Loosely facilitated group interaction intended to obtain opinions and reach level of consensus thru discussion dynamics related to one or more topics
  - Pros:
    - Provides dynamic interchange of individual thoughts and ideas
    - Can support voting process and subjective level of prioritization
    - Potential application of non-parametric statistical method
  - Cons:
    - Difficult to control group interactions – extroverts often predominant providers of ideas. Introverts play minimum role in idea generation (lost opportunity)
    - Discussions difficult to control without establishing rules limiting discussion – can lose valuable input of those less dynamic
    - Difficult to identify and prioritize ideas in terms of importance.
    - Rarely achieve consensus of group individuals taking control of group discussion.

Nominal Group Technique

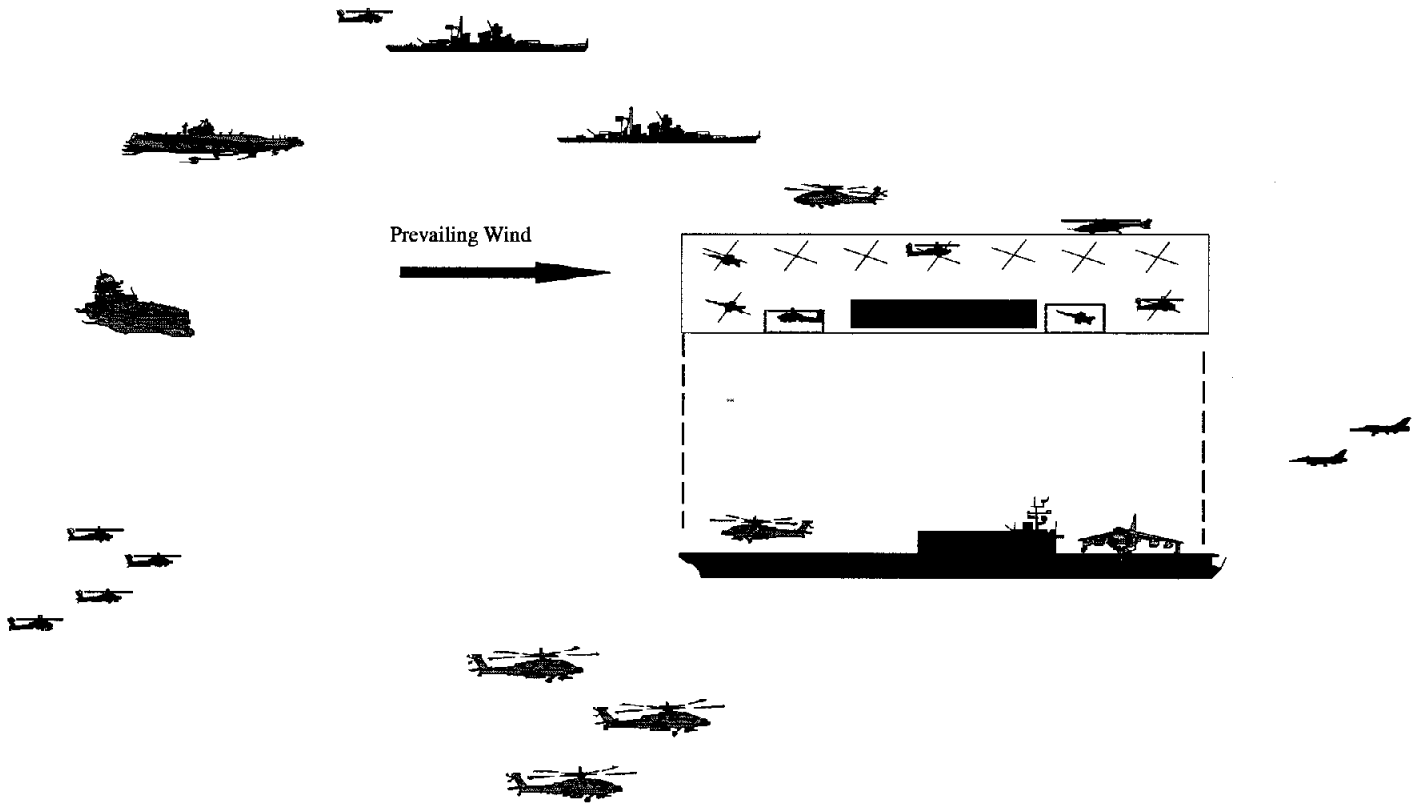
- Facilitates small to large group dynamics intended to obtain consensus related to pre-specified topic(s)
  - Pros:
    - All participants given direct opportunity to provide ideas without interference from others (control of interactions)
    - Works with groups that can be in hundreds
    - Since all attendees in group required to participate, final products more universally accepted
    - Set of high level ideas always emerge regardless of group size (normally clear separation in idea groupings and prioritization of importance)
  - Cons:
    - Must be thoroughly facilitated by one or more persons (e.g. Large groups, broken down into groups of 20 to 25 – each subgroup requires facilitator)
    - Rehearsal required to ensure each step of technique conducted in sequence

Dendritic Analysis Process

- Facilitated, organized process involving groups of no more than 20 to decompose a stated problem into its lowest relevant components
  - Pros:
    - Effective means of tracing all threads of problem to form relevant issue questions that, when answered, will collectively resolved problem
    - Allow rudimentary prioritization of issues and sub-issues to allow focus on those considered most important to group
    - Excellent method to determine all interactions that can occur that is related to problem needing resolution
  - Cons:
    - Requires substantial time to decompose and trace relevant threads
    - Difficult to control interactions. Without close facilitation, group can wander outside of problem focus area
    - Extroverts have tendency to control discussion and direction. Procedures can be established that opens inputs from all (NGT)

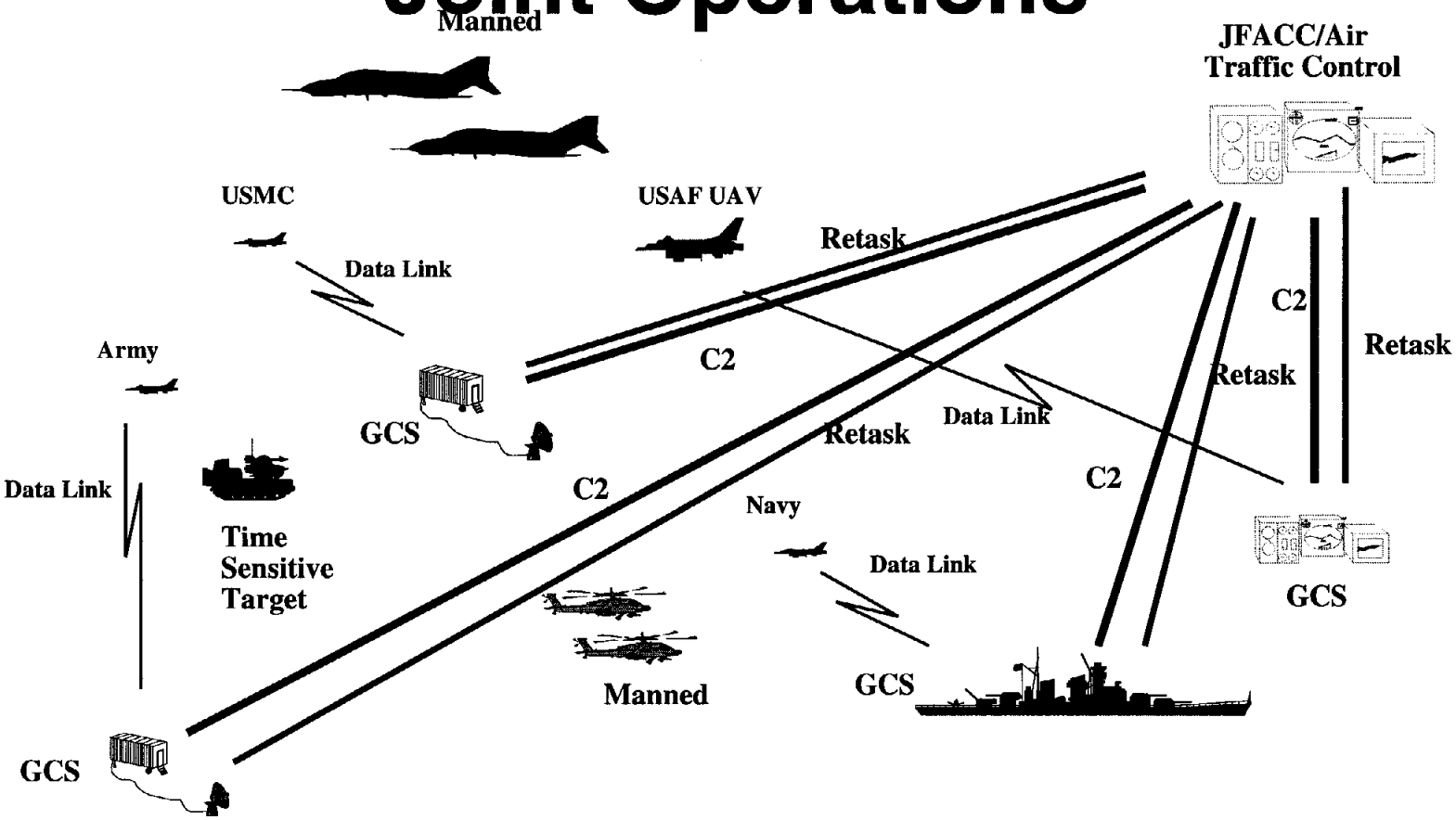
Development of a Problem Statement

STEP 1: "Draw a Picture" E.G. Mixed Helicopter & Fixed Wing Ops

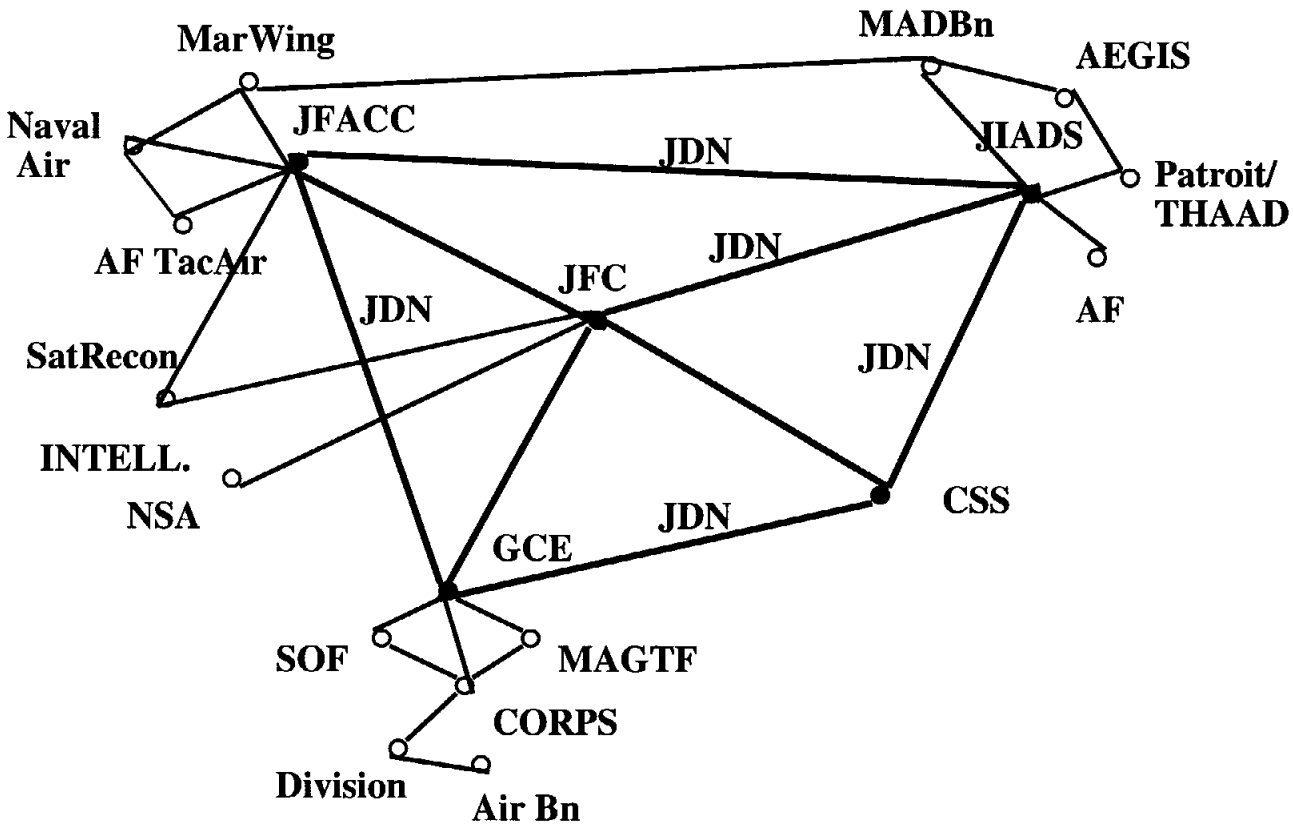


Focus: TTPs/Training/Ship-helo compatibility

Step 1: Draw a Picture e.g Battlefield Integration of UAVs in Joint Operations



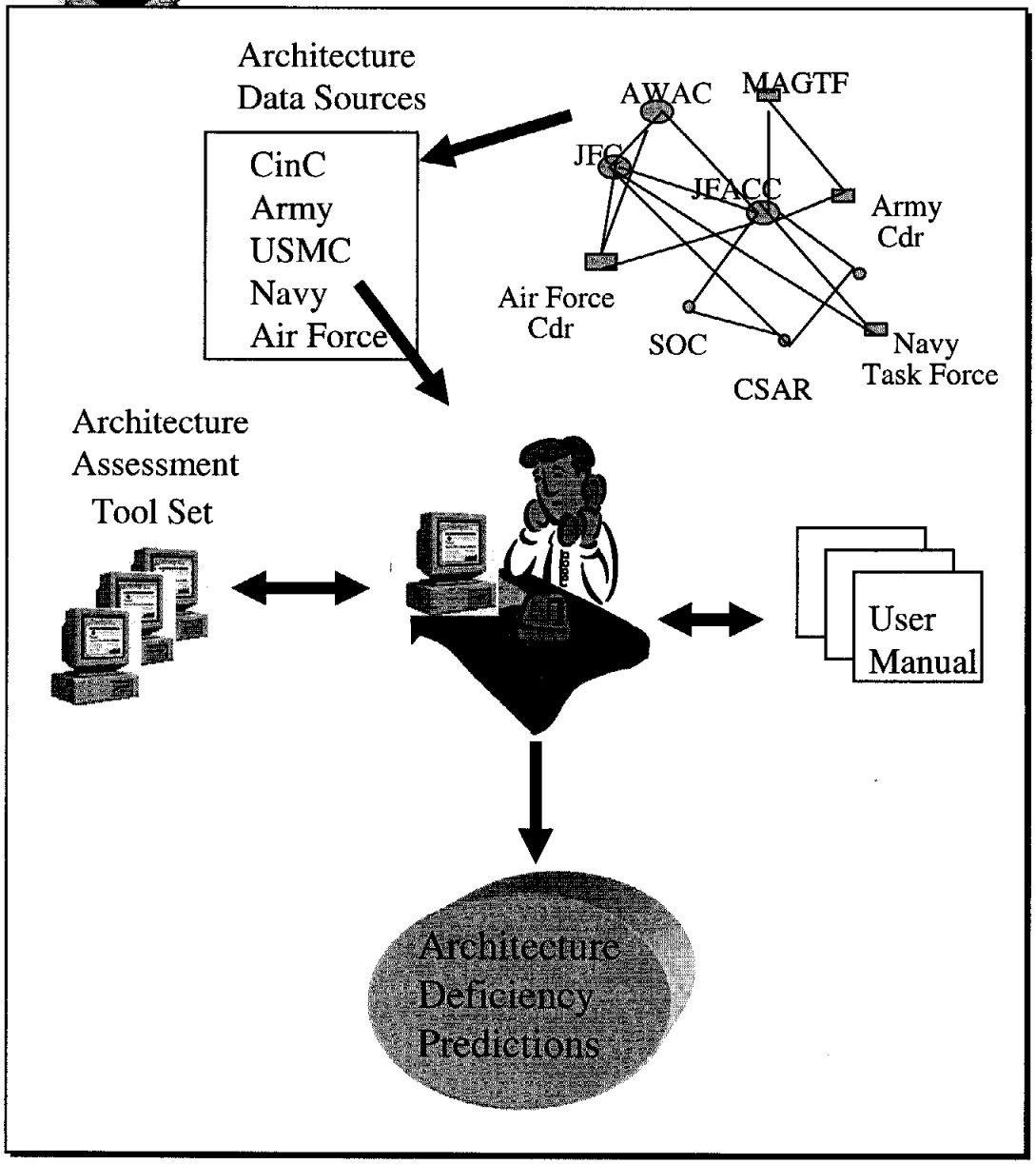
Step 1: Draw a Picture
e.g. C4ISR Architecture



Focus: JTTPs/Comm Architecture

JMACA Test Approach

Test Article: JMACA Assessment Methodology

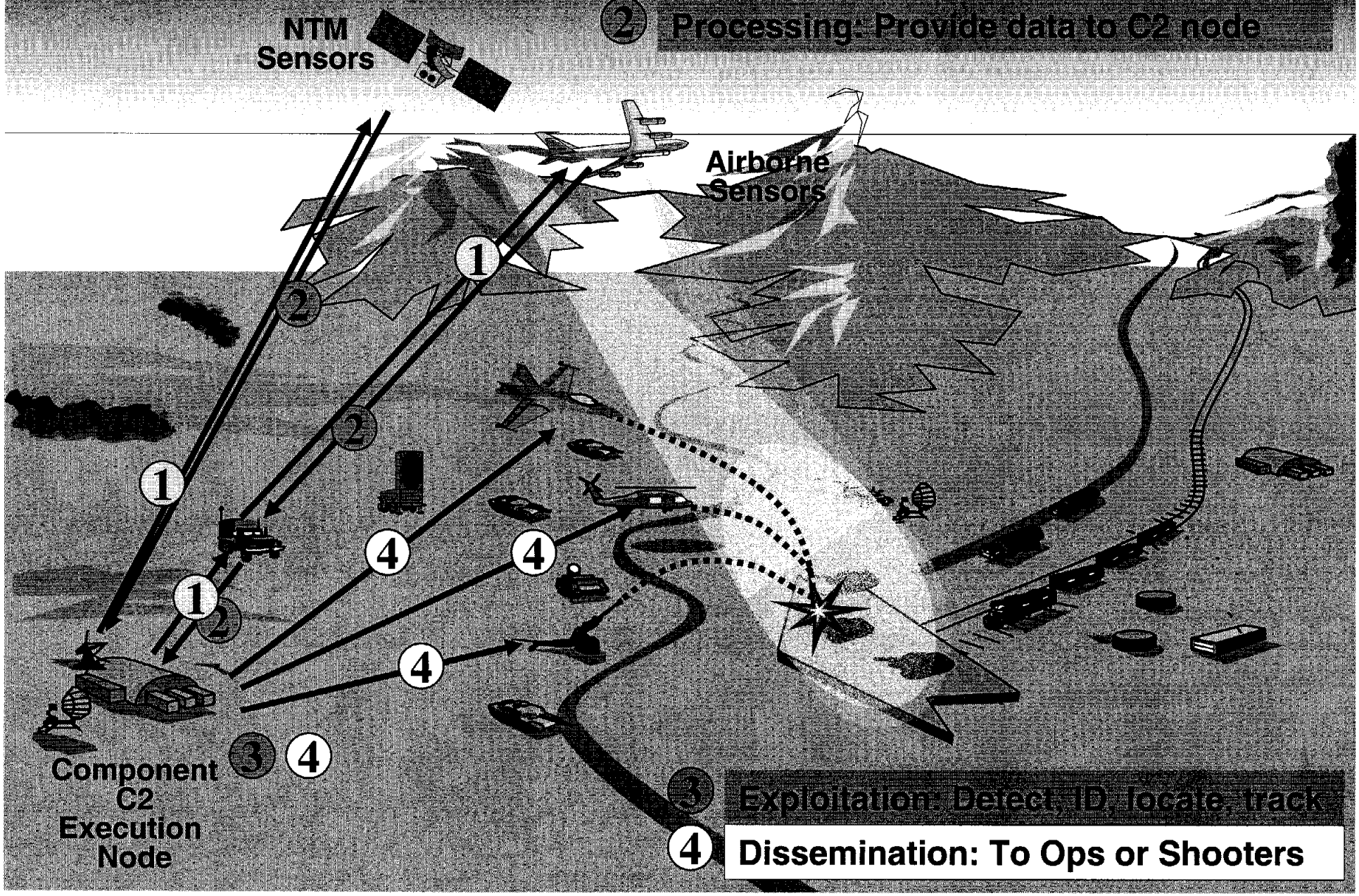


Test Focus

- Access to Architecture Data Sources
- Ability of operator(s) to input data from architecture data sources
  - Data entry procedures
  - Human computer interface (HCI)
  - Data Formats
- Ability Operator(s) to use Methodology
  - Computer based tools (JTIRA, …)
  - JMACA Users Manual
  - Training package
- Ability of Operator(s) to conduct analysis
  - Computer based analysis tools
  - JMACA developed analytical methods
- Validation of JMACA methodology and supporting computer based tool set
  - Accuracy of architecture deficiency predictions
  - Suitability of methodology and tools to support CinC and Service's architecture assessment needs (reliability, transport-ability, compatibility,training, etc)
- Evaluation of HCI with computer based prediction and analysis tools
- Impact on Joint TTPs for developing JC4ISR architectures

TPED Example

1. Tasking: Direct sensors where to look
2. Processing: Provide data to C2 node



3. Exploitation: Detect, ID, locate, track
4. Dissemination: To Ops or Shooters

Step 2: Develop JT&E Problem Statement

- Concise (one to two sentences)
  - Use unambiguous terminology
  - Scope operational problem that must be addressed
  - Supports issue questions
  - Majority of user population agrees with statement
- Examples:
  - Joint military operations and exercises have revealed difficulties in effectively and efficiently prosecuting time-sensitive surface targets in an area of responsibility and/or joint operating area.
  - Current joint helicopter operations lack coherent integrated and standardized tactics, techniques, and procedures which restrict Joint Force Commanders options during contingencies.

JT&E Problem Statement (Cont'd)

- Verbiage pitfalls:
  - Words with a lot of baggage (e.g. efficient, effective, capability, impact, etc). Each word must be carefully decomposed to ensure that meaning and intent are preserved (e.g. effective - attrition rate, rounds placed on target, ratio of fire missions successfully completed)
  - Ambiguous words that have no distinct meaning (e.g. degree of something, adequacy, sufficiency, etc)
  - Words that are very broad in meaning and interpretation - lacks descriptive adjectives and verbs (e.g. Supports military operations - - "military operations" is very broad - use adjectives to scope problem such as amphibious operations or air ops)
  - Beware of Boolean connectors (e.g. "and/or" - requires both conditions to be met)

Development of Issues and Sub-issues

JT&E Issues and Sub-issues

- Issues provide focus and direction for test events
  - Sub-issues help narrow focus
- Issues stated as question and must be explicit.
- Test team must consider "testability" of issue and decomposition into one or more sub-issues
- Dendritic analysis process provides means to decompose each issue to smallest constituent parts (e.g. data elements).
- Issues must be refined when dendritic decomposition fails. Often change of one or more words in issue question results from discussions with domain experts or examination of relevant documentation

Refining Program Issues (example)

- Original: What are the effects of enhancements on the combat effectiveness and efficiency of a JTF to employ operational firepower in providing joint fire support to its component land and amphibious maneuver forces?
- Problem: compound issue with several sub-issues --> "effectiveness", "efficiency", "land forces", "amphibious forces"
- Revised: Is the weaponeering assessment process effective to support joint targeting of time-sensitive land and amphibious surface targets?
  - Note: meaning of each word must be considered e.g. what is meant by "effective to support joint targeting?". Think in terms of measures e.g ratio of kills to number munitions released during a battle

Develop Sub-Issues

- A sub-issue is a subset of a larger program issue
- Be sufficiently explicit to derive a testable hypothesis* by quantitative or qualitative (scaled) measurement
- Example:
  - Sub-issue: Will a change in weaponeering assessment process result in an increase in enemy casualties in support of targeting time-sensitive land surface targets?
  - Sub-issue: Will a change in weaponeering assessment process result in an increase in enemy casualties in support of targeting time-sensitive amphibious surface targets?
  - * Hypotheses: a statement that can be considered to be true for the purpose of investigation or argument

Identification of Test Criteria

Specify Evaluation Criteria

- Quantitative explanation of a issue (forms the hypothesis)
- Acceptance criteria for measuring improvement
- Usually statements of required performance (e.g. expected results of changes to JTTPs)
- Normally expressed as thresholds or numerical range and must be unambiguous
- Either quantitative (measurement) or qualitative (scaled judgment)
- Based on opinion of appropriate subject matter experts or derived from appropriate manuals and documents
- Not all issues/sub-issues have associated criterion. Where there is no historical baseline, criterion will often evolve from baseline test case.

Specify Criteria (example)

- Sub-issue: Will a change in weaponeering assessment process result in an increase in enemy casualties in support of targeting time-sensitive amphibious surface targets?
- Criteria: A change in the weaponeering targeting procedure used by a JTF staff will result in an increase in enemy casualties of 10 percent or more
  - Ho: The change will result in less than 10% increase in enemy casualties
  - H1: The change in procedure will result in a 10% or more increase in enemy casualties

Development of JT&E Measures

Develop Measures (MOE & MOP)

- A measure is a mathematical relationship that describes operation or efficiency of a system or process. Stated in terms of measure of effectiveness (MOE) or measure of performance (MOP).
- MOE: Quantifiable value expressing effectiveness of a system or process under test. Directly measurable.
- MOP: Quantifiable value that expresses performance or capability of a system or process under specified set of conditions at human-machine level task level. Directly measurable.
- Measures determine the number of test events required to answer the issue under test based on a desired statistical confidence level (sample size or number of test iterations)

Rules for Meaningful Measures

- Rule: A measure must be "measurable"
- Rule: A measure should be mathematically oriented
  - Quantitative measures expressed in form of equation and have numbers providing means to calculate equation
  - Qualitative measures can be presented in terms of ratios or scaled values - N out of M respondents agreed (questionnaires or surveys)
- Rule: A measure directly addresses the test criterion, is explicit, and is unambiguous (when applicable)
- Examples of bad or weak measures:
  - "Degree of utility" --> "degree" is unmeasurable and "utility" needs to be explicitly defined to be measurable and unambiguous
  - "Adequacy of data translation" --> "adequacy is ambiguous - forces a qualitative assessment when a quantitative measure could have been used (e.g. percent data translated)

Rules for Meaningful Measures (Concluded)

- Ease of completing a process --> ambiguous measure requiring a qualitative assessment
- Elapsed time to acquire --> Not a measure. It is a data element that can support a measure (e.g. mean time to acquire includes an "elapsed time" component)
- Accuracy of isolated personnel location --> "accuracy" is not a measure. It is ambiguous and must be defined. An appropriate measure for "accuracy" could be: mean number of errors, probability of locating personnel, etc.
- Number of recovery attempts --> Not a measure. It is a data element that can support a measure
  - (e.g. Probability of recovery given an attempt)

Types MOEs and MOPs

- **Quantitative:**
  - probabilities, ratios, percents, statistical (e.g. population, sample), domain specific (circular error probable)
- **Qualitative:**
  - Delphi method and/or scaled questionnaire results (questionnaires are difficult to develop and implement - requires trained expertise to be effective)
- **Used to identify required data elements**
- **Example:**

$$\text{Weapon Firing Rate} = \frac{\text{Nbr Rounds Fired}}{\text{TimeEnd - TimeStart}}$$

Develop Measures Example

- **Issue:**
  - Can improvement in the weaponeering targeting procedure achieve a 10 percent reduction in target processing time?
- **MOE: Percent of targets processed in a specified time period (acceptance criteria)**

- **Mean Nbr Tgts Processed =** $\dfrac{\text{Total Nbr Tgts Processed}}{\text{Total Nbr Tgts Received}}$

- **MOP: Probability of engaging a assigned target during a specified time period**

$$\text{Probability}_{\text{Hit}} = \frac{\text{Sum (Number Targets Engaged)}}{\text{Total Number Targets Assigned}}$$

Identify Data Requirements

Specify Essential Data Elements

- Why data elements important?
  - Reason for conducting JT&E → collect data
  - Provides information required to calculate measures (MOE & MOP) and perform "evaluation" to answer issues
  - Refines planned scenario (s) that must be designed to facilitate data generation and collection
  - Supports determination of data collection instrumentation required to conduct test
- Association of measure to data element
  - Data to be collected MUST be directly relevant to measures (variables in the measure equation)
  - If data has no measure relationship, need to review reason for expending resources or reevaluate issue

Develop Test Scenarios

Data Elements (Example 1)

- Measure: Mean time to engage assigned targets

$$\text{Mean Time to Engage} = \frac{\text{Sum}^{n}_{I+1}(\text{Time}_{End} - \text{Time}_{Begin})}{\text{Total Number Tgts Engaged}}$$

Data Elements:

- Target type
- Time target engagement began
- Time target engagement ended
- Date (Julian date or calendar date) [Provides means to research data collection problem]
- Weather Conditions (possible effects on time to engage that may be considered to explain an aberrations)
- Clarifying comments

Data Elements (Example 2)

- **Measure: Probability of hitting a specified target given an attempt**

$$\text{Probability}_{\text{Hit}} = \frac{\text{Sum Number Target Hits}}{\text{Total Number Attempts}}$$

- **Data Elements:**
  - Target type
  - Test event number
  - Target Hit
  - Target Miss
  - Date of attempt
  - Time of attempt
  - Weather Condition at time of attempt

Develop Test Scenarios and Data Collection Procedures

- Test scenario(s) describe scope of test in terms of resources required
- Scenario must support collection of data for evaluation of test issues
- Scenarios exercise range of variability of test concept and provide means for generating required data
- Each scenario must describe participants/test resources (personnel, materials, equipment), their interrelationships, and test environment (atmospheric conditions, terrain, visibility, etc.)
- Scenario requirements guides test venue selection
- Data Collection procedures based on scenario uniqueness - guides data collection methods (manual, automatic, field instrumentation)
- Use verified & validated simulation scenarios to supplement live test data, as appropriate (Note: Joint Test Director accrediting agent for simulations that meet the JT&E's requirements)

Test Scenario Example

- **Scenario:**
  - **Four remotely controlled T81 tanks moving over level desert terrain at a speed of 30 mph in daylight, clear skies, with a visibility of at least 10nm on a heading of 30 degrees from UTM grid coordinate NP634921 engaged by an A-10 aircraft firing Hellfire missiles.**
  - **Data Collection Instrumentation:**
    - **Tank instrumentation to record weapon impact points and position (e.g. GPS, GPS time tag)**
    - **Tank sensor warning and defensive system recorders (e.g. telemetry relay)**
    - **Aircraft position: aircrew, time-space-position-information (TSPI), GPS, range radars, slant range**
    - **Weapon release info: time released, time of impact, impact point (e.g GPS, GPS time tag)**

Constraints On IDRL

- Sample size (# test events that must occur)
  - Statistical significance demands a large number
  - JT&E budget limited
  - Factorial test planning methods can help reduce sample size
- Test resources availability
- New instrumentation development and existing equipment modification
- May need to augment live/real tests with simulations
  - Increases risk, possibly cost, definitely schedule

Summary

- Properly conducted Dendritic Analysis process will provide means to develop executable test program
- Supports identification of required test resources (participants and instrumentation)
- Necessary for development of Consolidated Resource Estimate

JT&E Analyst Reference Handbook

- Provides reference material that can help in JFS and PTP
  - Nominal Group Technique to obtain consensus - JWAG
  - MOE examples – POINT OF MOST FAILURES
  - Failure definition/scoring conferences - model for process to adjudicate data anomalies and unexpected data collection results
  - Questionnaire construction manuals to support scaled questionnaire/interview question development
  - VV&A guide for M&S
  - Human Factors T&E Manual
  - Reliability, Availability, Maintainability Primer DoD 3235-1H to assist in determining sample sizes and confidence intervals