A Framework for Software Acquisition Early Warning Indicators

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Outline

- Background
- The Framework for Software Acquisition Early Warning Indicators
- Relationship between Factors and Metrics
- Use of Profiles for Early Warning Indicators
- Conclusion
- Contact Information
- Acronym List

History of the "Bell-Ringing" Initiative

- **Beginning in 1999, failures in high-profile acquisition reform programs began to emerge at SMC**
  - Performance deficiencies, extensive software defects
  - Large, unanticipated cost and schedule overruns
- **Extent and severity of software-related problems was not understood until late in the development life cycle**
- **One SMC System Program Director expressed the desire to have a set of "bell-ringing criteria"**
  - Early warning indicators of actual or potential problems in one or more factors that influence success of software-intensive system acquisitions
  - Signal the need for additional management attention to the influencing factors

Aerospace "Bell-Ringing" Research

- **In 2001, Aerospace began a research project to develop a comprehensive set of "bell-ringing criteria"**
- **Factors adversely influencing the success of software-intensive system acquisition were determined to extend far beyond those controlled by the contractor's software development teams**
- **Research project first step: Define a Framework for identifying and classifying these factors**
  - Framework to define the relationships and interactions of the factors
  - Framework to include quantitative indicators derived from the factors
  - These indicators to provide foundation for satisfying the realistic information needs of the acquisition manager

The Approach for Describing the "Bell-Ringing" Factors

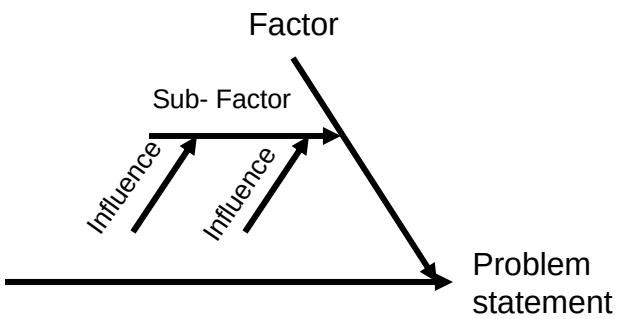
Problem:

- Needed a simple way to model systemic influences and factors
- Needed to translate to Cause (influence) and Effect (factors)
- Needed an intuitive Information presentation

Approach:

- Ishikawa Diagrams selected for
  - Ease of use
  - Automated tools
  - Low training needs

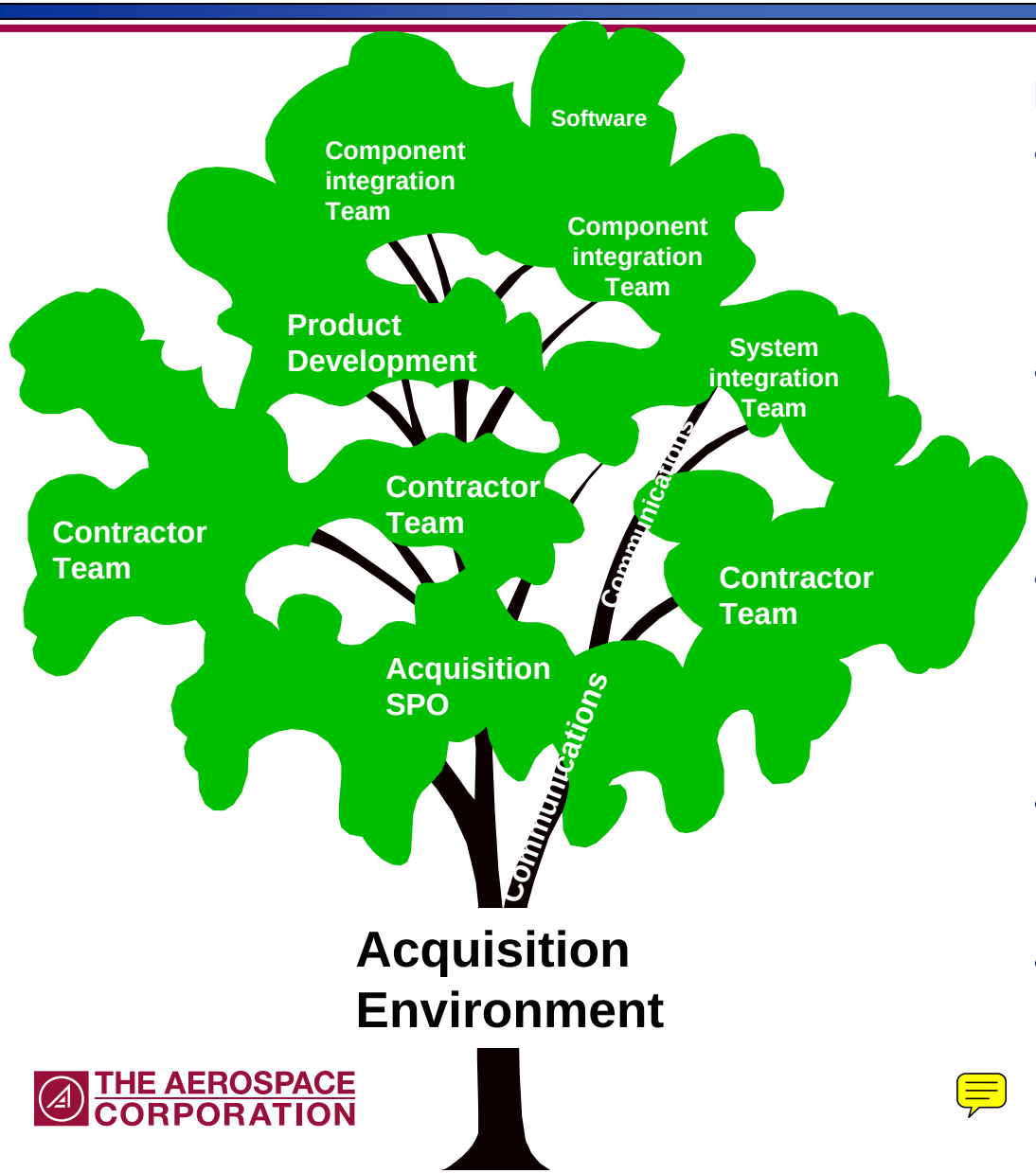
Example:



Definitions:

- **Problem Statement -** A statement of the problem. Usually provided in terms of a necessary improvement.
- **Factor -** Possible causes of the problem.
- **Sub-factor -** These are the lower level factors of the subset problem.
- **Influence -** Measurable feature of the factor or sub-factor.

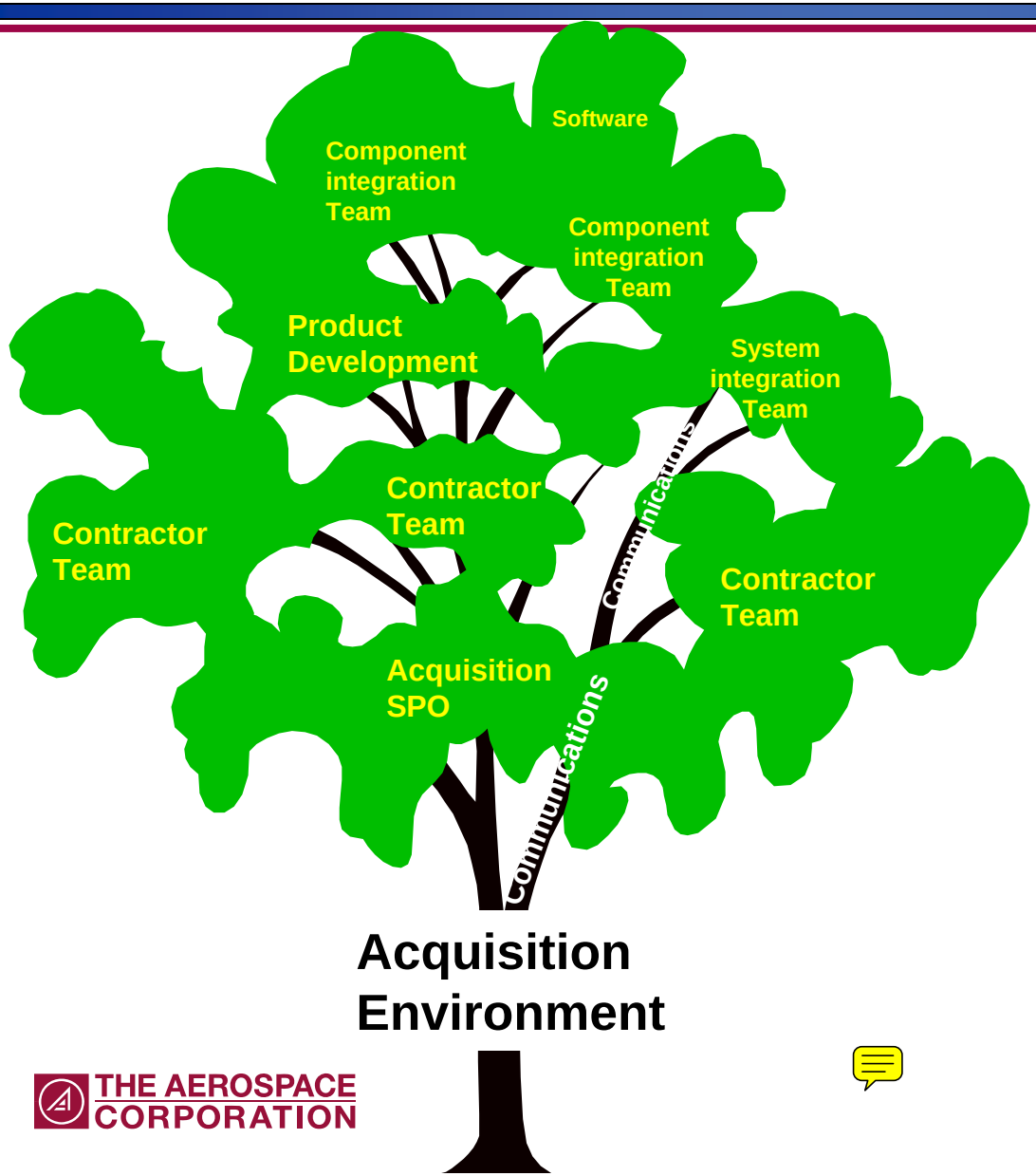
The Framework



Factors:

- **Acquisition Environment –** Organizations external to the SPO, including acquisition management, user/operator, independent test and certification, interfacing systems, other government agencies or departments, etc.
- **Acquisition System Program Office -** The SPO itself, from the SPO director down to the lowest level personnel, plus Aerospace, other FFRDCs and SETA contractors that support the SPO.
- **Contractor Team –** Contractor organizations external to program's engineering organizations, including corporate and program management, quality assurance/software quality assurance, contracts/scheduling, organizational process groups.
- **Product Development –** Contractor engineering organizations, including systems engineering, software engineering, specialty engineering, test organizations, CM, etc.
- **Communications –** Interrelationships among the first four factors, such as customer satisfaction, communication and agreements.

Acquisition Environment Factor



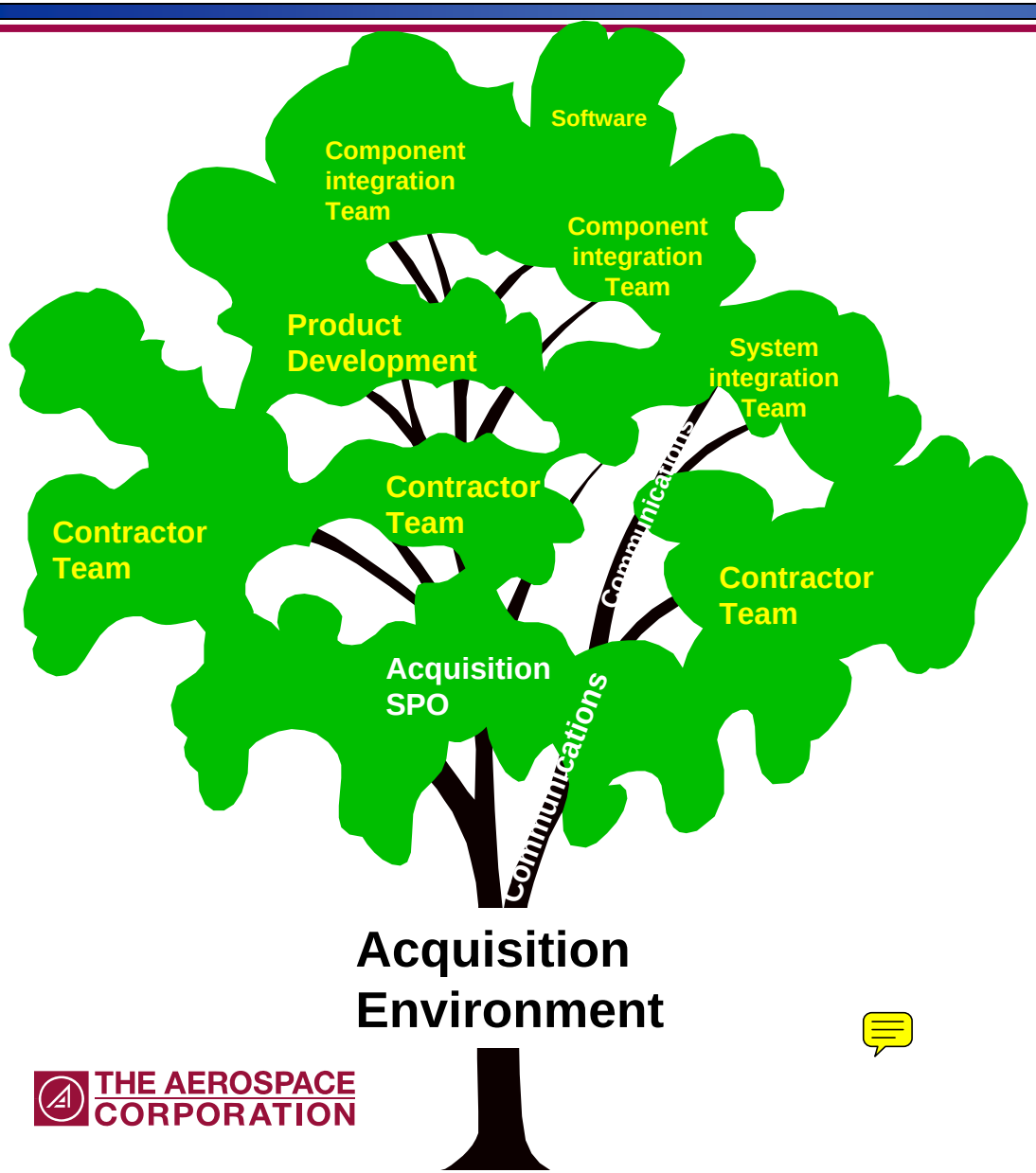
Sub-Factors:

- **Resources -** Number, quality, availability and sufficiency of acquisition environment personnel, test and operational facilities and other external resources.
- **Processes –** Number, stability and adequacy of policies, regulations, laws, processes.
- **Products -** Size, stability and adequacy of external products, including user requirements (ORD, ICDs), CONOPS, testing/certification requirements, cost and schedule requirements, GFE/GFI; suitability and stability of new technologies mandated for use.
- **Schedule –** External schedule constraints, including site/facility, testing, interfacing systems, and GFE/GFI schedules.
- **Motivation -** Perceived motivation, incentives, degree of risk aversion, strength of need.
- **Product Quality -** Number of measured defects in delivered products, product complexity

Examples: Acquisition Environment Factor

- **Restrictions on availability of operational facilities for installation and testing**
  - ❖ Concurrent use conflicts
- **Imposition of new policies and regulations on the program**
  - ❖ Ambiguity and lack of actual program experience in implementing new policies/regulations
- **Volatility in externally imposed system requirements**
  - ❖ ORD changes, difficulties in negotiating ICDs
- **Volatility in program funding**
  - ❖ Total and by fiscal year
- **Quality problems in externally produced system products**
  - ❖ Defects, complexity in system requirements

Acquisition System Program Office (SPO) Factor



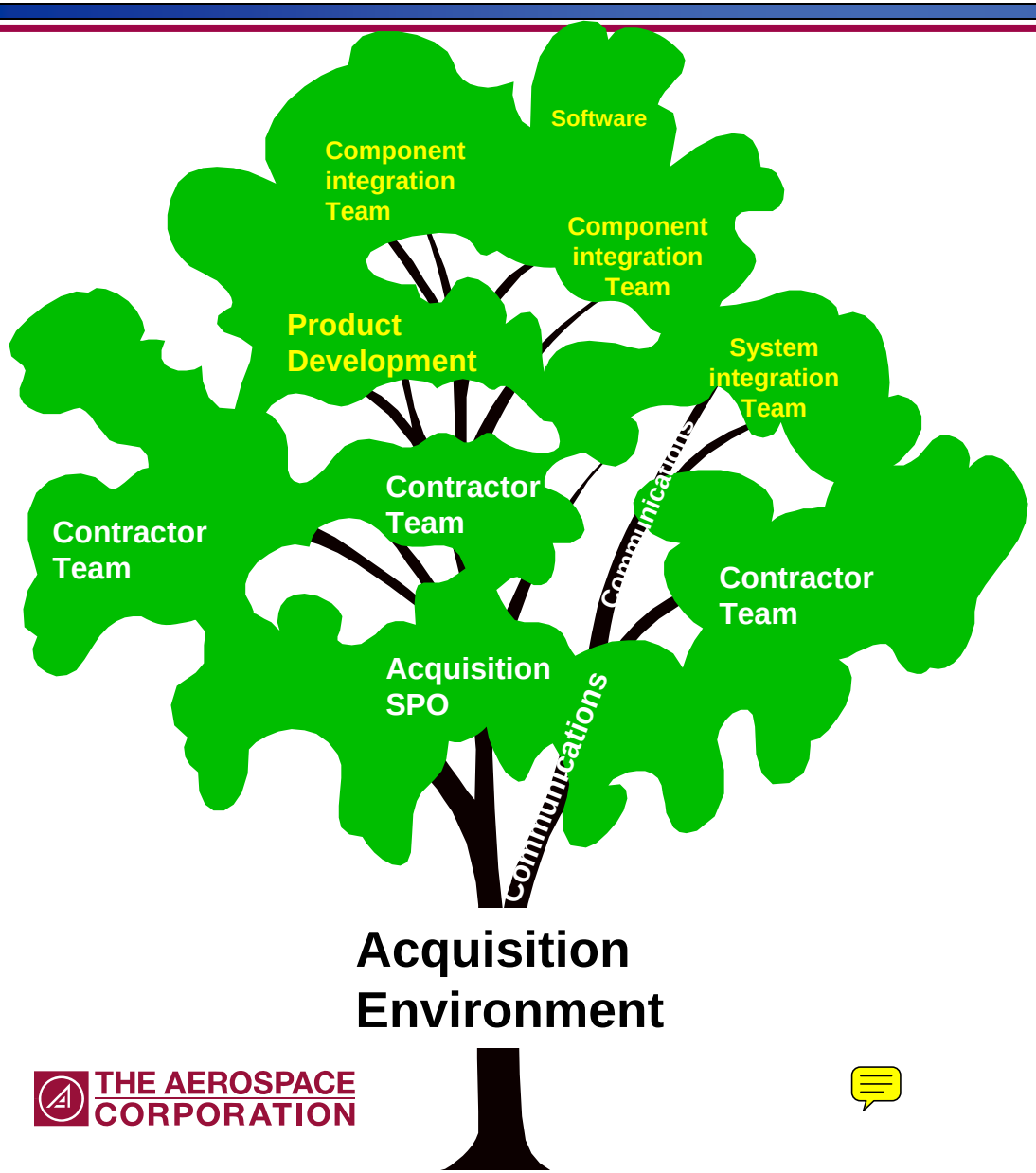
Sub-Factors:

- **Resources -** Personnel, financial, environment and support resources constraining SPO performance.
- **Process Performance -** Effectiveness, compliance and efficiency of procedures and practices in use by the SPO.
- **Products -** Size, stability and adequacy of SPO products, including: contractual requirements, RFP, acquisition strategy, TEMP, etc.
- **Schedule and Progress -** SPO schedule, critical path performance, progress and cycle time.
- **Motivation -** Personal and professional motivation, incentives, degree of risk aversion.
- **Organization -** Number and complexity of relationships in SPO organization and its influencing external organizations, including the degree of geographic dispersion.
- **Product Quality -** Number of measured defects in SPO products, product complexity.

Examples: Acquisition SPO Factor

- **Sufficiency and stability of assigned personnel**
  - ❖ Quantity, experience, training; tasks per person
- **Stability and rework in SPO products**
  - ❖ Externally driven and internally driven; defects and churn
- **Quality of program cost and schedule estimates**
  - ❖ Estimating accuracy, schedule compression
- **Cycle time within the SPO**
  - ❖ Decision making, issue resolution, action item completion
- **SPO organizational structure**
  - ❖ Number of different organizations within and external to the SPO
  - ❖ Complexity of interrelationships, geographical dispersion
- **Implementation of critical processes within the SPO**
  - ❖ Risk management, configuration management, etc.

Contractor Team Factor



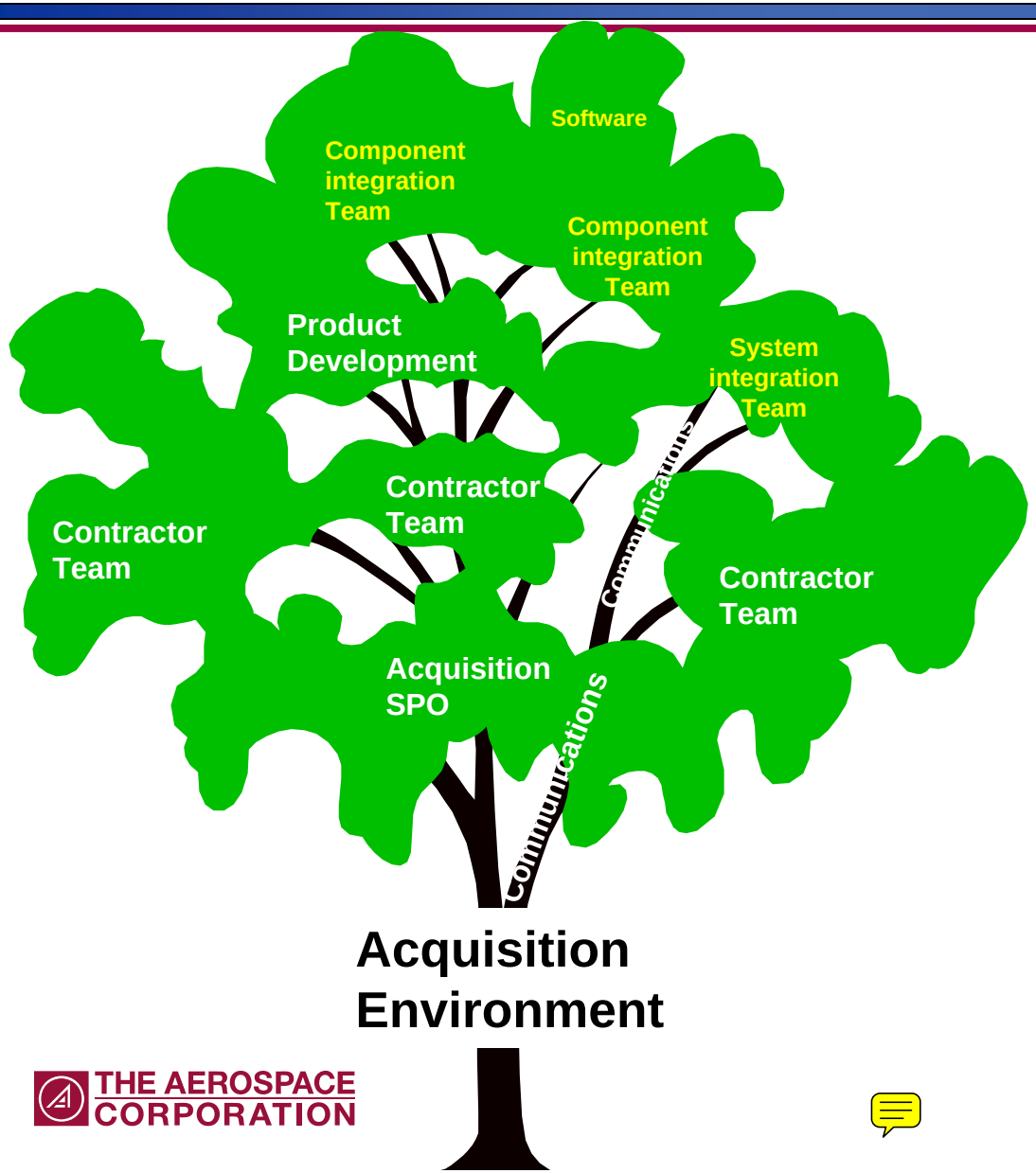
Sub-Factors:

- **Resources -** Number, quality, availability and sufficiency of personnel, test facilities and other contractor team resources.
- **Processes -** Number, stability and adequacy of the policies and processes available for use by the development organizations.
- **Products -** Size, stability and adequacy of requirements imposed on the development organizations; readiness of technology imposed on the development organizations.
- **Schedule -** Schedule, cost and cycle time constraints imposed on the development organizations.
- **Motivation -** Personal and professional motivation, incentives, degree of risk aversion.
- **Product Quality –** Number of measured defects in products, product complexity.

Examples: Contractor Team Factor

- **Availability of test resources/facilities**
  - ❖ Conflicts among shared resources, schedule constraints
- **Process infrastructure available to programs**
  - ❖ CMM/CMMI level
- **Imposition of new policies on the program**
  - ❖ Corporate acquisitions or reorganizations
  - ❖ Process improvement initiatives
- **Imposition of cost and schedule constraints on development**
  - ❖ Constantly increasing productivity goals
- **Cycle time within this factor**
  - ❖ Decision making, financial reports

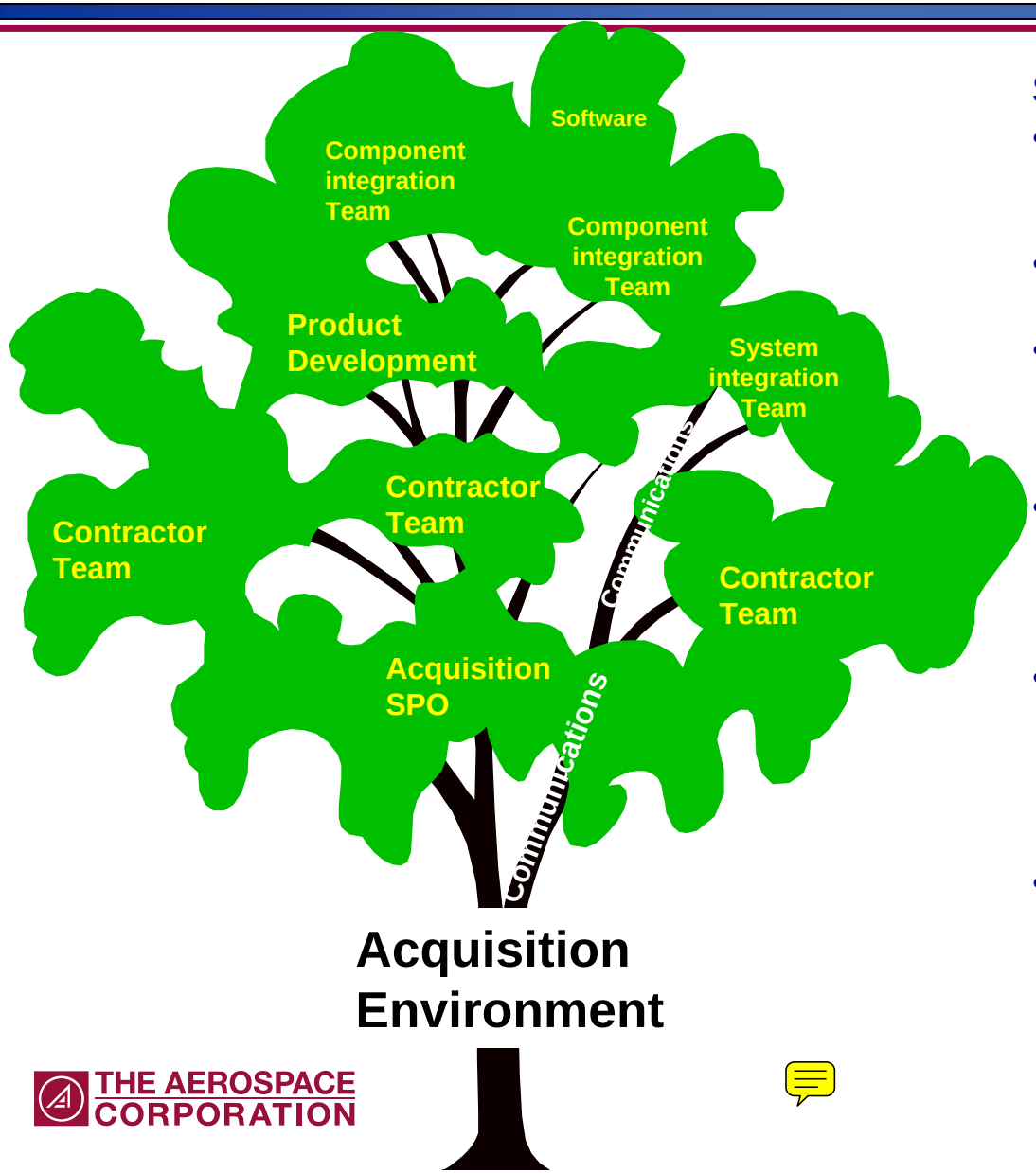
Product Development Factor



Sub-Factors:

- **Resources and Cost –** Resources necessary to accomplish system development, including personnel, costs, lab and test facilities.
- **Process Performance –** Effectiveness, compliance and efficiency of the program's engineering processes.
- **Products -** Size, stability and adequacy of intermediate and final engineering products (e.g., requirements, design, code, test).
- **Schedule and Progress -** Schedule, critical path performance, progress and cycle time.
- **Motivation -** Personal and professional motivation, incentives, degree of risk aversion.
- **Organization -** Number and complexity of relationships in contractor organization, including the degree of geographic dispersion.
- **Product Quality -** Number of measured defects in engineering products, product complexity.

Communication Factor



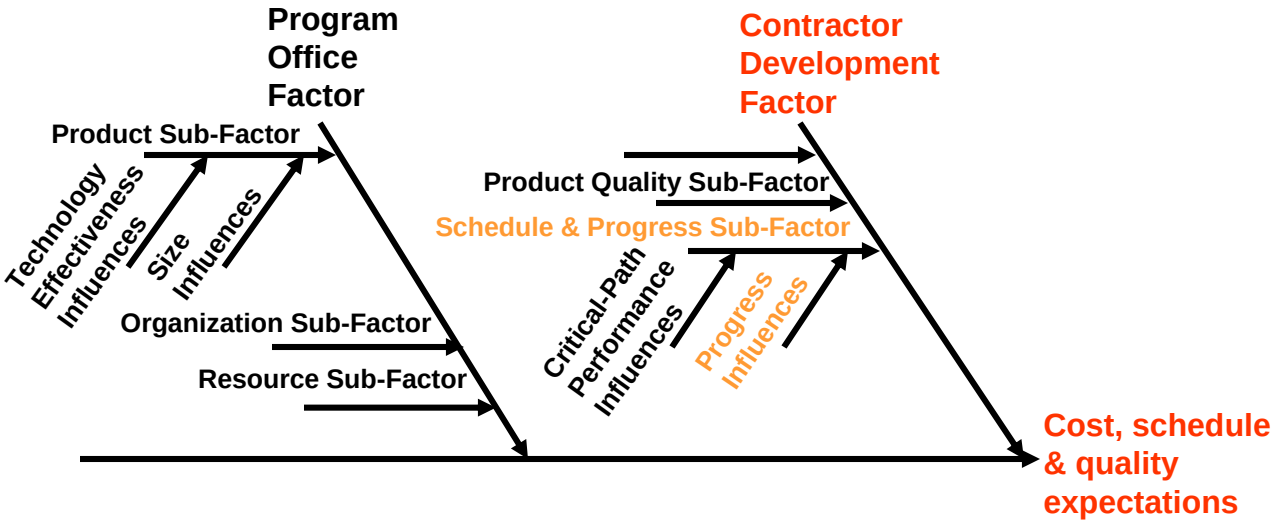
Sub-Factors:

- **Customer Satisfaction -** Degree of customer satisfaction among the organizations in the acquisition framework.
- **Motivation -** Interpersonal relationships across the acquisition framework.
- **Information Mismatch -** Information mismatches across the acquisition framework (e.g., in requirements interpretations, cost and schedule estimates).
- **Communicating Across Boundaries -** Adequacy of the infrastructure for communicating across the acquisition framework.
- **Arrangements Across Boundaries -** Number, stability and adequacy of various arrangements that cross the boundaries of the acquisition framework (e.g., contracts, tasking, MOUs).
- **Organizational Complexity –** Number and complexity of relationships among the organizations across the boundaries of the acquisition framework; cycle time across boundaries.

Examples: Communication Factor

- **Mismatches across the acq. environment, acq. SPO, contractor team, and product development factors**
  - ❖ Requirements interpretations
  - ❖ Interpretations of new policies/regulations
  - ❖ Cost and schedule estimates
- **Excessive cycle time across boundaries**
  - ❖ Decision making cycle time, time to definitize contract changes
- **Unplanned tasking across boundaries**
  - ❖ Tasks to SPO from Pentagon level
  - ❖ Tasks to contractors from SPO
- **Relationships across boundaries**
  - ❖ Quantity, complexity, geographical dispersion of organizations
  - ❖ Interpersonal relationships

The Relationship Between Factors and Metrics



Influence	Metric
Critical-Path Performance	Slack Time Lead Time Lag Time
Progress	Requirements Traced Problem Rpts Closed Reviews Completed Units Integrated Action Items Done

- A **metrics** problem with Reviews Completed
- Translates into a sub-factor **issue** in Progress Influence
- Which identifies a **focus area** of Schedule and Progress Sub-factor
- This then **targets** the Contractor Development Factor as the assignable cause of the problem
- Which culminates in higher **risk** of a cost, schedule or quality failure

An Approach for Translating These Causal Factors into Early Warning Indicators

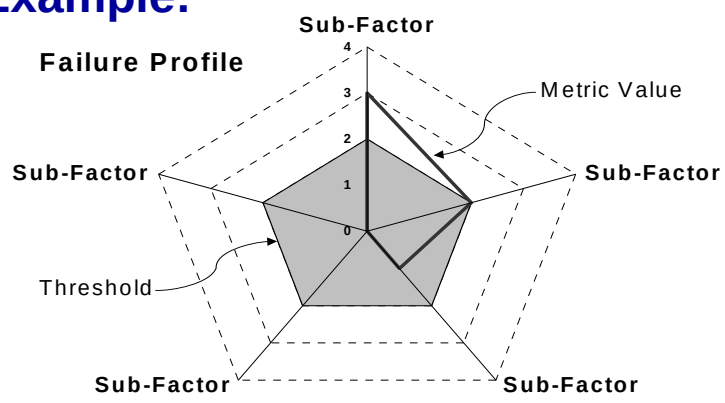
Problem:

- No one factor causes program failure
- Patterns of failure have been observed and documented
- Attention to a single factor often causes program failures

Approach:

- Use metrics as the early evidence of failure
- Compare metrics to known cases of failure

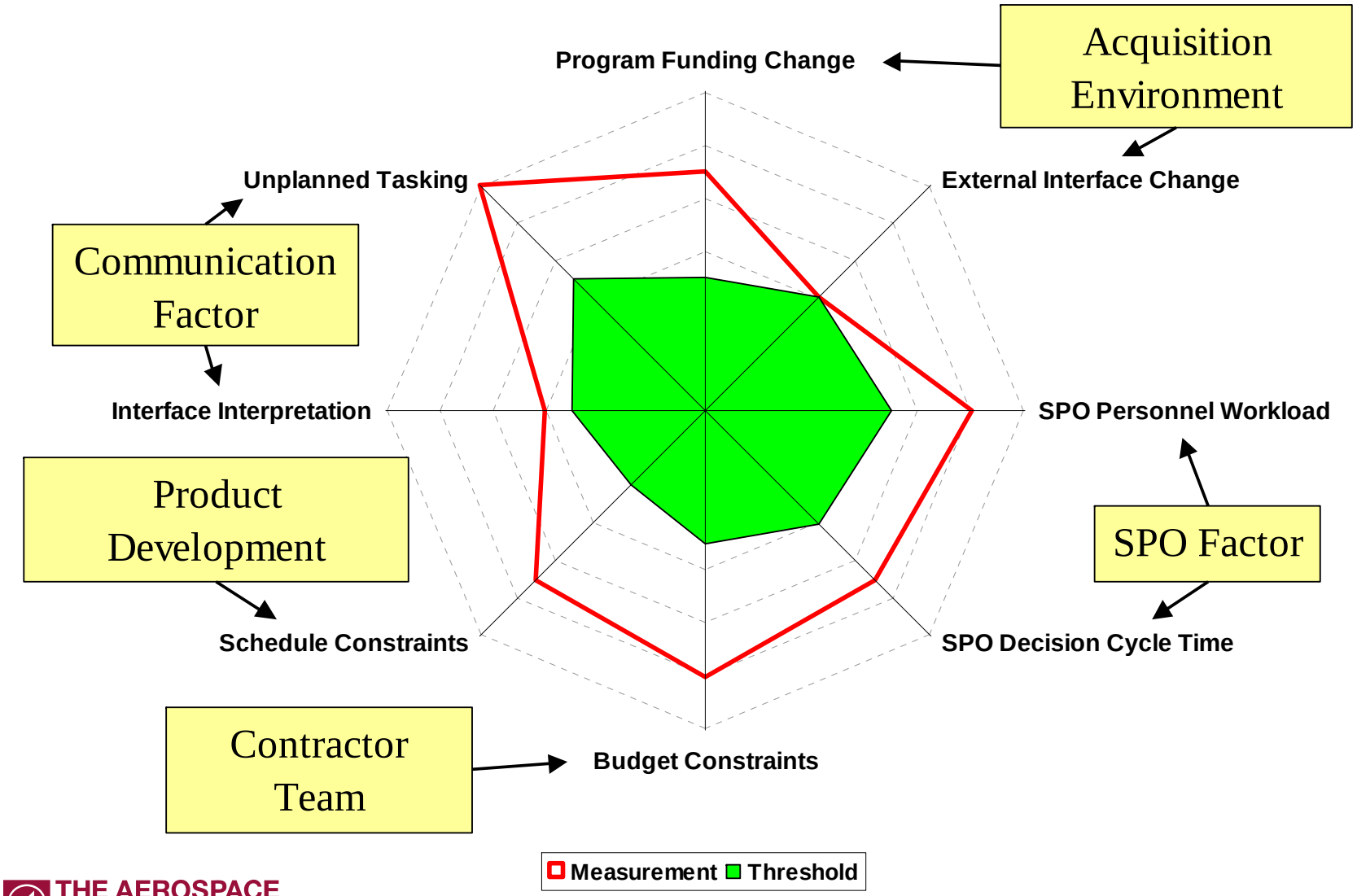
Example:



Definitions:

- **Failure Profile -** Provides a general target area grouped by focus areas.
- **Sub-factor -** Represents a set of focus areas that have been identified as applicable to this failure profile.
- **Threshold -** A metric value that should not be breached without appropriate action being taken.
- **Metric Value -** Measurable feature of the factor or sub-factor.

Profile: Volatility in a Cost-Constrained Environment



Conclusion

- **To date, this research has developed a Framework for Software Acquisition Early Warning Indicators**
  - ❖ Expresses the factors, sub-factors and influences that affect the successful acquisition of software-intensive systems
- **Next step: Define the actual "bell-ringing criteria"**
  - ❖ Define the metrics to be used to measure the influences
  - ❖ Define failure thresholds and profiles
- **The "bell-ringing criteria" will provide a static view of the program state (e.g., a snapshot in time, or a sequence of snapshots in time)**
  - ❖ Full comprehension of the program state also requires an understanding of the complex, dynamic interactions of the factors influencing acquisition success

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Acronyms

CM	Configuration Management
CMM	Capability Maturity Model
CMMI	Capability Maturity Model Integration
CONOPS	Concept of Operations
FFRDC	Federally Funded Research and Development Center
GFE	Government Furnished Equipment
GFI	Government Furnished Information
ICD	Interface Control Document
MOIE	Mission Oriented Investigation and Experimentation
MOU	Memorandum of Understanding
ORD	Operational Requirements Document
RFP	Request for Proposal
SETA	Systems Engineering and Technical Assistance
SMC	Space and Missile Systems Center
SPO	System Program Office
TEMP	Test and Evaluation Master Plan
USAF	United States Air Force