A SIMPLE PRESCRIPTION FOR REQUIREMENTS SUCCESS
Who Is Jeff Grady?

CURRENT POSITION
President, JOG System Engineering
System Engineering Consulting and Education Firm

PRIOR EXPERIENCE
U.S. Marines
General Precision, Librascope Division
Customer Training Instructor, SUBROC and ASROC ASW Systems
Ryan Aeronautical Company (later Teledyne Ryan Aeronautical)
Field Engineer, AQM-34 Series Special Purpose Aircraft
Project Engineer, System Engineer, Unmanned Aircraft Systems
General Dynamics, Convair Division
System Engineer, Cruise Missile, Advanced Cruise Missile
General Dynamics Space Systems Division
Functional Engineering Manager, Systems Development Department

FORMAL EDUCATION
SDSU, BA Math; UCSD, Systems Engineering Certificate;
USC, MS Systems Management with Information Systems Certificate

INCOSE
First Elected Secretary, Founder, Fellow, ESEP

AUTHOR
System Requirements Analysis (2), System Integration, System Validation
and Verification, System Engineering Planning and Enterprise
Identity, System Engineering Deployment, System Verification, System
Synthesis, System Management
Systems Jeff Grady Worked On

USN/Librascope
ASROC/SUBROC
Computer Systems

USAF/GD Convair AQM 129
Advanced Cruise Missile

USAF/GD Atlas Missile

USAF/Ryan AQM-81 Firebolt
Ryan Aeronautical War Birds

USAF/Ryan Models 147G, NX, H, and J at Bien Hoa, SVN

USAF/Ryan AQM-34L Tom Cat 58 Combat Missions

U.S. Navy/Ryan Model 147SK

USAF/Ryan BGM-34C
The Prescription Plan

• Introduce ideas to be applied

• Program preparation steps
  - Preparation process overview
  - Specification templates
  - Organizational structure and responsibilities
  - Modeling preferences and modeling work product capture
  - Specification map

• Program implementation steps

• Modeling overview
  - Traditional Structured Analysis as a Universal Architecture Description Framework (UADF)
    - RAS-Complete to collect the modeling results
  - MSA and PSARE teamed up as a UADF
  - UML teamed up with SysML as a UADF

• Specification publishing and a look into the future
Requirement Defined

- Something wanted or necessary.
- Something essential to the existence or occurrence of something else.
- A necessary characteristic or attribute of something, entity, or item.
What is a Specification?

A specification contains all of the requirements for a given item.
A Current Reality

• Many system engineers and managers have the opinion that their organization does not perform requirements analysis and specification publishing well.

• Unfortunately, many of these engineers and managers are right about their organization's performance in this area.

• There seems to be a void of knowledge among these engineers and managers about how to avoid this problem, about how to bring about an improvement in the performance of their organization.
Some Elementary Logic

• If what you are now doing is not working well, it stands to reason that if you keep doing what you are doing then the outcome will continue to be unsatisfactory (a variation on the definition of insanity to expect otherwise)
• You may have to undergo a change in how you accomplish this work.
• The purpose of this presentation is to offer one effective route to correcting the problem.
• There may be other ways to fix the problem as well but this one will work.
The Top-Level Program Structure

• The development organization should follow a pattern of first defining the requirements in a set of performance specifications, one for each entity in the system. These system and item specifications must also include the system test and evaluation and item qualification verification requirements respectively.

• Step two is to accomplish synthesis in a trio of transformations: (1) requirements to design solutions, (2) design solutions to material acquisition, and (3) available materials to manufactured product.

• When the design for an item is essentially complete, develop a detail specification for use as the basis for item product acceptance verification subsequent to manufacture.
The Top-Level Program Structure

• The third program step is to verify that the manufactured product satisfies the requirements in the specifications that should have driven the design.
  – System Specification content drives system development test and evaluation plans and procedures.
  – Item Performance Specification content drives item qualification verification plans and procedures.
  – Item Detail Specification content drives item acceptance test plans and procedures accomplished on every production article.

• Accomplish the three fundamental steps within a sound management infrastructure
The System Development Sequence
In Summary

• Define the problem
  – Specifications

• Solve the problem
  – Design, procurement/material, and manufacturing

• Prove it
  – Verification

• All within a sound technical management infrastructure
The Prescription - Preparatory Steps

1. Establish a written criteria of acceptability for all specifications created.
2. Select a set of specification templates including one for every kind of specification the enterprise will ever have to prepare on a program.
3. Base requirements definition on the use of models.
4. Select a set of models that form a universal architecture description framework (UADF) that is comprehensive relative to system, hardware, and software entities.
5. Coordinate the specification template paragraph structures with responsible functional departments and analytical models that will be applied in identifying specification content.
The Prescription - Preparatory Steps

6. Coordinate the specification template paragraphing structure with the models used such that all of the requirements derived from one model fall into one portion of the specification paragraphing structure.

7. Craft a template for a structured analysis modeling work product capture document within which a program structured analysis model base can be configuration managed – System Architecture Report (SAR).

8. Train personnel in the application of assigned models such that they arrive on a program ready to accomplish assigned work. A common process on all programs can be a part of this by encouraging process repetition.
The Prescription - Implementation Steps

1. Where multiple modeling sets are employed in an enterprise, determine models that will be applied on the particular program for system, hardware, and software entities. Work toward a common set (a UADF).

2. Select templates for system, hardware, and software entity specifications.

3. Build a specialty engineering scoping matrix for the program and coordinate discipline expectations with team budget limitations.

4. Form a PIT that will accomplish system level structured analysis using selected models identifying the content of the system specification and specifications corresponding to the top level IPPT.
The Prescription - Implementation Steps

5. Apply functional models to determine what the system and entities must do and how well they must do it. Coordinate performance requirements analysis with product entity and interface needs.

6. Apply models for interface, specialty engineering, and environmental requirements analysis.

7. Each IPPT should come aboard with a specification and program planning complete for the entity for which they will be responsible.

8. IPPT continue lower tier structured analysis with appropriate models.

9. Employ a program-wide RAS-Complete in a computer database to capture the requirements flowing from all of the models used.
The Prescription - Implementation Steps

10. Employ a computer application that sets the RAS database filter to a particular product entity and part (performance or detail) and orders the database content by paragraph number so as to print a specification to screen or paper.

11. Apply sound risk management techniques and formally review all specification and changes for release.

12. Configuration manage released specifications and changes.

13. Require that every new specification and every change to a previously approved specification be reviewed and approved in response to a written criteria for acceptability.

14. Use the verification requirements in the system and item performance specifications as the basis for system DT&E and item qualification verification plans and procedures.
The Prescription - Implementation Steps

15. Maintain three-dimensional traceability (vertical, longitudinal, and lateral) to the extent possible.
The Prescription in a Picture

Specifications

Review, Approve, and Publish Specification

System Architecture Report

Requirements Analysis Sheet (RAS)

Prepare SAR

System Architecture and Requirements Analysis Work

Generic Work

Requirements Work Organizing Matrix

Enterprise Organization Structure

Specification Structure Template

Preferred Model (UADF)
Universal Architecture Description Framework Approach

Model the Problem Space
Annotating Artifacts With MID

List Artifacts in RAS in MID Alphanumeric Order

Allocate Requirements

Derive Requirements

Employ Universal Format For Entity Specification

And on to Verification

Published Specifications

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12E2A-20

JOG System Engineering
How Shall We Organize?

Functional Departments With Specification Responsibilities
MIL-STD-961E Specification Types

- PERFORMANCE (Part I)
- DETAIL (Part II)
- SYSTEM
  - ITEM
  - SOFTWARE
  - MATERIAL
  - PROCESS
Requirements Documentation

Principal Assignments

RESPONSIBILITIES ARE ASSIGNED BY PIT AS A FUNCTION OF ARCHITECTURE TEAM ASSIGNMENTS

ON-BOARD COMPUTER

COMPONENT PROCUREMENT

COMPONENT CI

COMPONENT IN-HOUSE

SYSTEM

SEGMENT

VEHICLE SEGMENT

PRIME ITEM

LAUNCH VEHICLE

PRIME ITEM

CORE VEHICLE

SUBSYSTEM IN-HOUS

AVIONICS SUBSYSTEM

SUBSYSTEM IN-HOUSE

GUIDANCE & NAV SUBSYSTEM

RESPONSIBILITY ASSIGNMENT

SYSTEM ENGINEERING

DESIGN TEAMS (IF ASSIGNED)

SUBSYSTEM GROUPS OR TEAMS

DESIGN GROUPS

VERSION 12.0

12E2A-23

© JOG System Engineering
Requirements Documentation Responsibilities by Element Type and Level

SYSTEM SEGMENT

NUMBERS IN LOWER RIGHT CORNER ARE DEPARTMENT NUMBERS FOR RESPONSIBILITY
A Template
Using the Six-Section Military Format as a Basis

1 Scope
2 Applicable Documents
3 Requirements
4 Verification
5 Packaging
6 Notes
# Specification Template, Model Preference, and Responsibility Map

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### Specification Template, Model Preference, and Responsibility Map

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Lateral Traceability
Models as Characteristic List Builders

PRIMITIVES CAPTURED IN RAS-COMPLETE (Ideally in a database)

ITEM SPECIFICATION

PUBLISH

STRUCTURED ANALYSIS TOOLS
Building Universal Specifications
With Perfect Modeling Alignment

CUSTOMER NEED STATEMENT
USER REQUIREMENTS DOCUMENTATION
ENVIRONMENTAL STANDARDS

3.1.1 CUSTOMER NEED STATEMENT
3.1.2 USER REQUIREMENTS DOCUMENTATION
3.1.3 ENVIRONMENTAL STANDARDS

3.1.4 CUSTOMER NEED STATEMENT
3.1.5 USER REQUIREMENTS DOCUMENTATION
3.1.6 ENVIRONMENTAL STANDARDS

3.1.7 CUSTOMER NEED STATEMENT
3.1.8 USER REQUIREMENTS DOCUMENTATION
3.1.9 ENVIRONMENTAL STANDARDS

3.2 PROBLEM SPACE MODELING RESULTS
3.3 INTERFACE DEFINITION
3.4 ENTITY DEFINITION
3.5 SPECIALTY DEFINITION

3.6 PERFORMANCE REQUIREMENTS ANALYSIS
3.7 INTERFACE REQUIREMENTS ANALYSIS
3.8 SPECIALTY REQUIREMENTS ANALYSIS
3.9 ENVIRONMENTAL REQUIREMENTS ANALYSIS

UML
DODAF
MSA/HP
TSA
SYSML

PROGRAM MODELING AND REQUIREMENTS ANALYSIS
ENVIRONMENTAL REQUIREMENTS ANALYSIS
SPECIALTY REQUIREMENTS ANALYSIS
INTERFACE REQUIREMENTS ANALYSIS
PERFORMANCE REQUIREMENTS ANALYSIS
ENTITY DEFINITION
INTERFACE DEFINITION
ENVIRONMENT DEFINITION
DYNAMIC DEFINITION
Three Ways to Capture the Modeling

- Within specification paragraph 3.1.3 on a program with few specifications
- In a system architecture report (SAR) referenced in paragraph 3.1.3
- Within the computer tool used to accomplish the modeling work with a reference in paragraph 3.1.3 to the tool content
Overview of Available Comprehensive Models

• Traditional Structured Analysis UADF
  – Functional modeling
  – Product entity and interface modeling
  – Specialty engineering modeling
  – Environmental modeling

• MSA/PSARE UADF

• UML/SysML UADF
TSA Function Allocation

FUNCTIONAL FLOW DIAGRAM

ALLOCATE FUNCTIONALITY TO THINGS IN SYSTEM

PLACE ALLOCATED ITEMS INTO SYSTEM PRODUCT STRUCTURE

PERFORMANCE REQUIREMENTS ANALYSIS PERFORMED ON ALLOCATED FUNCTIONALITY

PERFORMANCE REQUIREMENTS FOR ITEM FUNCTIONS ALLOCATED TO

MANUFACTURING BREAKDOWN STRUCTURE

DRAWING BREAKDOWN STRUCTURE

WORK BREAKDOWN STRUCTURE

INTERFACE ANALYSIS

MAKE-BUY PLAN

DEVELOPMENT ORGANIZATION STRUCTURE

CONFIGURATION ITEM ANALYSIS

SPECIFICATION TREE DEVELOPMENT

CONSTRAINTS ANALYSIS
TSA Interface Definition Models

SCHEMATIC BLOCK DIAGRAMMING

- Lines define interfaces
- Blocks are objects only from the product entity structure diagram

N-SQUARE DIAGRAMMING

- Marked intersections define interfaces
- Diagonal blocks are objects only from product entity block diagram
- Apparent ambiguity reflects directionality
### TSA Specialty Engineering Identification of Requirements

**PRODUCT ENTITY STRUCTURE**

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**PRODUCT ENTITY-SPECIALTY ENGINEERING MATRIX (DESIGN CONSTRAINTS SCOPING MATRIX)**

**SPECIALTY ENGINEERING REQUIREMENTS FLOW INTO THE INDICATED SPECIFICATIONS THROUGH THE RAS**

**SAR APPENDIX E**
TSA Environment Subsets

Some would add a software subset
Environmental Requirements Model

• **System**
  – Identify spaces within which the system will have to function
  – Select standards covering those spaces
  – For each standard, select parameters that apply
  – Tailor the range of selected parameters

• **End item**
  – Build three dimensional model of end items, physical processes, and process environments
  – Extract item environments

• **Component**
  – Zone end item into spaces of common environmental characteristics
  – Map components to zones
  – Components inherit zone environmental requirements
# RAS – Complete

## Using TSA UADF

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Lateral Traceability
Through the RAS and SAR
MSA/PSARE as a UADF

• PSARE provides a complete UDAF problem space model

• Alternatives for the solution space model
  – Simply use the PSARE architecture model but some parts still not covered so augment with environmental modeling and specialty engineering modeling
  – Replace the PSARE architecture model with the common solution space model set
    » Product entity structure identified by super bubbles
    » Specialty engineering scoping matrix and specialty models
    » Three-layered environmental model
    » Interfaces handled by "data flow"
    » RAS
MSA/PSARE
Sample System Analysis – Context Diagram Expansion
NOTE:

(1) Consider adding a function to permit testing of the filters by running the pump without feeding the spray pattern by returning the water

(2) No storage while measuring water pressure on both sides of the filters. A high pressure indication should be logged for an early maintenance response.

(3) Water used must be measured before the spray pattern rather than after.
INFLOWS

R18  local rainwater collected. This water should be filtered in some fashion at least to the extent that silt does not accumulate in the storage vessel.

R1Z  Water District water made available to increase stored water.

OUTFLOWS

R1T1  Water from storage for use in the facility water deluge. Some form of filtering is necessary to prelude debris jamming of the pump being fed. Related plumbing must be able to handle a 100 gallons per minute pump rate.

TRANSFORMATION

1. Output equals input except that if the vessel is open to the environment some stored water will be lost due to evaporation.

2. It is necessary for the storage vessel to have a capacity of TBD-1 gallons.

3. The storage vessel may be a tank of metal or fiberglass construction above ground or buried, a swimming pool, or a naturally appearing pond or one fashioned in the ground through an earth moving operation. A tower tank is not encouraged because of the owner requirement in paragraph 3.1.2.1.2 regarding appearance.
## A Data Dictionary Fragment

**Table C-1  Data Dictionary (Continued)**

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<td>A sufficiently high hazard index must trigger a fire fighting service request and start a clock measuring response time. This relationship starts the clock.</td>
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UML/SysML Entry
The Context Diagram Crutch
UML/SysML Dynamic Modeling Overview

1. Context Diagram
2. Top Level Use Case for Each Terminator
3. Possible Extended and/or Included Use Cases
4. Scenario Set For Each Use Case
5. Activity Diagram for Each Scenario
6A. Activity Diagram With Swimlanes
6B. Interaction Diagram for Each Scenario
5A. Sequence Diagram
5B. Communication Diagram
7. State Diagram
8. Product Entity Structure
9. Dynamic Analysis

Cycle to Lower Tiers

Requirements
UML/SysML Modeling

Use Case Analysis Example

Use Case Diagram
Followed By Dynamic Modeling of Use Cases
Hierarchical Structure for UML/SysML Analysis

SOFTWARE ENTITY A23

A23   Product Entity A23
C23   Top Level Use Case For A23
C23(1) Terminator
C23(11) Base Use Case
C23(111) Extended Use Case
C23(1111) Scenario
C23(11111) Sequence Diagram Used to Analyze C23(1111)

MASTER USE CASE C23

CONTEXT DIAGRAM TERMINATOR 4
C23(4)

CONTEXT DIAGRAM TERMINATOR 3
C23(3)

CONTEXT DIAGRAM TERMINATOR 1
C23(1)

CONTEXT DIAGRAM TERMINATOR 2
C23(2)

SUPPORTING CONSTRUCT
NOT PART OF THE MODEL

USE CASE C23(14)

USE CASE C23(13)

USE CASE C23(11)

USE CASE C23(12)

EXTENDED USE CASE C23(114)

EXTENDED USE CASE C23(113)

EXTENDED USE CASE C23(111)

EXTENDED USE CASE C23(112)

IF SECOND TIER NEEDED

SCENARIO C23(1114)

SCENARIO C23(1113)

SCENARIO C23(1111)

SCENARIO C23(1112)

COMMUNICATION DIAGRAM
C23(11114)

STATE DIAGRAM
C23(11113)

SEQUENCE DIAGRAM
C23(11111)

ACTIVITY DIAGRAM
C23(11112)

COMMUNICATION DIAGRAM NOT IN SysML
All Possible Inter-Model Transfers
Inter-Model Transfers
With a UML/SysML UADF
UML/SysML Cyclical Analysis

a. Product System Static Hierarchy (Structural Classifiers)
b. Node AX3 Activity Diagram
c. Node AX3 Sequence Diagram
d. Node AX3 State Diagram
e. Node AX3 Communication Diagram
Entity Identification Using UML/SysML

Borrowed From MSA
SAR Organization For UML-SysML
A Universal Model for the Future?

DODAF
OOA
IDEF
FA

NOT FULLY SUPPORTED?

To be pulled in by UPDM

DODAF
DODAF

UML/SysML
UML/SysML

UML
UML

RAS
RAS

UML-SysML UADF
UML-SysML UADF

MSA
MSA

PSARE
PSARE

PRODUCT ENTITY STRUCTURE MODEL
PRODUCT ENTITY STRUCTURE MODEL

INTERFACE MODEL
INTERFACE MODEL

THREE-TIER ENVIRONMENTAL MODEL
THREE-TIER ENVIRONMENTAL MODEL

SPECIALTY ENGINEERING SCOPING MATRIX
SPECIALTY ENGINEERING SCOPING MATRIX

TRADITIONAL STRUCTURED ANALYSIS UADF
TRADITIONAL STRUCTURED ANALYSIS UADF

VERSION 12.0
12E2A-57
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What Will the Future Look Like?

• A single model for the problem space - no matter how the specific product will be developed in hardware or software
• Requirements embedded in problem space models encouraging requirements compliance in design models with the specifications appearing in the form of models
• A connected series of models for design
• Inter-model effects observable directly rather than individual human interpretation of effects followed by conversation and action - can we do this?
• Verification linkage through models
• Eventual connection between the problem space modeling and CAD-CAM models.
• A business process model coordinated with engineering modeling
Model-Driven Challenges

• Will it be possible for managers to avoid whiplash due to the speed of the analytical process?

• Can we provide adequate exposure of the ongoing and dynamic modeling work to encourage sound management of the development process?

• Will it really be possible to build models that fully express the problem space essential characteristics (requirements) while permitting a solution space larger than a single solution?
The Computer Network Becomes a Team Member in Good Standing

Will there be room for human emotion in the development process? I hope so!
Development Evolution Timeline, Driving Methods Staging

- Document Driven Development
- Database Driven Development
- Model Driven Development
- Specification Standard Conflict Window

Rise in the Use of Implementable Models

05-15-2002 DATA UNSUBSTANTIATED

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Model Convergence On the Road to Enterprise Architecting

OMG MOF

BPDM UML CWM

SYSML UPDM

BPDM = Business Process Data Model
CWM =
UPDM = UML Profile For DODAF Modeling
Action Items For You as a System Engineer

- Continue your studies of requirements work
- Come to an understanding about UML and SysML
- Within your company and programs develop modeling skills and work toward simplifying your combined set of models into a universal framework
- Work toward correlating the SW and HW development work patterns so as to encourage more effective integration
- Join INCOSE/NDIA working groups that deal with the issues covered in this paper and offer your ideas.