CONCEPTS, REQUIREMENTS, AND DESIGN APPROACHES FOR BUILDING SUCCESSFUL PLANNING AND SCHEDULING SYSTEMS

PART I: A PROGRAMMATIC PERSPECTIVE
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PART II: A TECHNICAL PERSPECTIVE
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PRESENTATION OUTLINE

PART I: A PROGRAMMATIC PERSPECTIVE

• STATING THE MANAGEMENT CHALLENGE
• DISSECTING THE MANAGEMENT CHALLENGE
• RESPONDING TO THE MANAGEMENT CHALLENGE
• FOCUSING THE TECHNICAL PERSPECTIVE
• SUMMARY

PART II: A TECHNICAL PERSPECTIVE

• REQUIREMENTS THAT ARE UNLIKE OTHER SYSTEMS
• GOOD AND BAD STARTING POINTS FOR THE DESIGN
• PROJECTING THE CONSEQUENCES OF OPERATIONS CONCEPTS
• SUMMARY
STATING THE MANAGEMENT CHALLENGE

HOW CAN THE TRADITIONAL PRACTICE OF SYSTEMS ENGINEERING MANAGEMENT, INCLUDING REQUIREMENTS SPECIFICATION, BE ADAPTED, ENHANCED, OR MODIFIED TO BUILD FUTURE PLANNING AND SCHEDULING SYSTEMS THAT POSSESS LIFECYCLE EFFECTIVENESS?

DISSECTING THE MANAGEMENT CHALLENGE

TRADITIONAL SYSTEMS ENGINEERING MANAGEMENT PROCESS

- REQUIREMENTS SPECIFICATION
- DESIGN
- IMPLEMENTATION
- TEST
- OPERATIONS
DISSECTING THE MANAGEMENT CHALLENGE

REDESIGNING THE SYSTEM BASED ON OPERATIONAL EXPERIENCE

PLANNING AND SCHEDULING SYSTEMS

ANY HUMAN-COMPUTER DECISION-SUPPORT SYSTEM THAT DETERMINES AND/OR REDETERMINES HOW SHARED RESOURCES WILL BE MANAGED OVER TIME

RESOURCES
- ON-ORBIT
  - SPACECRAFT
  - PLATFORMS
  - INSTRUMENTS
  - EXPERIMENTS
  - ASTRONAUTS
- LAUNCHES
  - LAUNCH PADS
  - LAUNCH VEHICLES
  - PAYLOADS
- COMMUNICATIONS
- GROUND
  - FACILITIES
  - COMPUTERS
  - ANTENNAS
  - OPERATORS

DECISIONS
- TO ASSURE ACCESS TO RESOURCES CONSISTENT WITH PROGRAM OBJECTIVES

OBJECTIVES
- ACCURATE AND TIMELY ASSIGNMENTS (AND REASSIGNMENTS) OF RESOURCES
- IDENTIFICATION, AVOIDANCE, AND/OR RESOLUTION OF CONFLICTS
- EFFECTIVE AND COMPLEMENTARY HUMAN/COMPUTER INTERACTION
- UNCOMPLICATED AND STRAIGHT FORWARD HUMAN/HUMAN INTERFACE
DISSECTING THE MANAGEMENT CHALLENGE

LIFECYCLE EFFECTIVENESS

OPERATIONAL EFFECTIVENESS

DOING THE RIGHT JOB EFFICIENTLY

EXTENSIBILITY

EASY ACCOMMODATION OF CHANGE
RESPONDING TO THE MANAGEMENT CHALLENGE

ADAPTATIONS TO THE TRADITIONAL PRACTICE OF SYSTEMS ENGINEERING MANAGEMENT

FOR DOING THE RIGHT JOB EFFICIENTLY

FOCUS SYSTEMS ENGINEERING EFFORT ON DEFINING AND BUILDING THE RIGHT SYSTEM, RATHER THAN ON DEFINING AND FOLLOWING THE RIGHT PROCESS

KEY TO BUILDING THE RIGHT SYSTEM LIES IN DETERMINING AND IMPLEMENTING THE RIGHT REQUIREMENTS IN THE APPROPRIATE OPERATIONS CONTEXT

10 ADAPTATIONS ARE RECOMMENDED

FEATURED ARE:

- REQUIREMENTS AND OPERATIONS CONCEPTS VALIDATION
- PROTOTYPING
- OPERATIONS CONSIDERATIONS AS EVALUATION CRITERIA

RESPONDING TO THE MANAGEMENT CHALLENGE

ADAPTATIONS FOR DOING THE RIGHT JOB EFFICIENTLY

1. ESTABLISH AND MAINTAIN COMPETING ALTERNATIVE OPERATIONAL CONCEPTS

2. ADD OPERATIONAL EFFECTIVENESS CRITERIA TO THE EVALUATION PROCESS USED IN REQUIREMENTS AND DESIGN REVIEWS

3. START WITH GENERAL FUNCTIONAL REQUIREMENTS AS A BASELINE

4. ADD OPERATIONAL EFFECTIVENESS TO CRITERIA FOR DESIGN ACCEPTABILITY

5. UTILIZE FORMAL PROTOTYPING PLAN FOR CONTROL DURING SYSTEM DEVELOPMENT

6. USE WORKING SOFTWARE AS DETAILED DESIGN DOCUMENTATION

7. DEVELOP A TECHNIQUE FOR MAKING DECISIONS TO BORROW TOOLS, APPROACHES, OR SOFTWARE VS. BUILDING TOOLS, APPROACHES, OR SOFTWARE

8. ENFORCE AN END-TO-END IMPLEMENTATION STRATEGY — IMPLEMENT IN LAYERS NOT SEGMENTS

9. FORMALLY ESTABLISH OPERATIONAL EFFECTIVENESS AS A TEST CRITERION

10. DEVISE TEST PLANS WHICH CERTIFY OPERATIONAL EFFECTIVENESS IN REAL OR SIMULATED OPERATIONAL ENVIRONMENTS
RESPONDING TO THE MANAGEMENT CHALLENGE

ADAPTATIONS TO THE TRADITIONAL PRACTICE OF SYSTEMS ENGINEERING MANAGEMENT

FOR EASY ACCOMMODATION OF CHANGE

ELEVATE REQUIREMENTS SPECIFICATION FROM INDIVIDUAL SYSTEM LEVEL TO CLASS LEVEL

• REQUIREMENTS AT THIS LEVEL CAN BE PRECISE AND UNAMBIGUOUS
• GENERAL ARCHITECTURE EXISTS AT THIS LEVEL TO INCORPORATE NEW REQUIREMENTS

RECOGNIZE GENERAL CASE / SPECIAL CASE RELATIONSHIPS AND DESIGN FOR GENERAL CASE

5 ADAPTATIONS ARE RECOMMENDED

RESPONDING TO THE MANAGEMENT CHALLENGE

REQUIREMENTS SPECIFIED AT THE CLASS LEVEL

DECISION SUPPORT SYSTEMS

PLANNING & SCHEDULING

SYS X

SYS Y

SYS Z

REQ’MTS AT THIS LEVEL CAN BE:
• COMPLETE
• UNAMBIGUOUS
• MEASURABLE
• STATIC

SOME REQ’MTS AT THIS LEVEL MAY BE:
• INCOMPLETE
• AMBIGUOUS
• UNQUANTIFIABLE
• DYNAMIC

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RESPONDING TO THE MANAGEMENT CHALLENGE

REQUIREMENTS NEED TO BE ELEVATED

TRANSITION TO A GENERALIZED DESCRIPTION OF PLANNING AND SCHEDULING

FROM

• CREWTIME, POWER, WATER
• EXPERIMENT PERFORMANCE
• SLEEP/EAT CYCLES

INDIVIDUAL SYSTEM LEVEL

TO

• RESOURCES
• ACTIVITIES
• GENERAL TEMPORAL RELATIONS

PLANNING & SCHEDULING CLASS LEVEL

RESPONDING TO THE MANAGEMENT CHALLENGE

ADAPTATIONS FOR EASY ACCOMMODATION OF CHANGE

1. CHOOSE TOOLS THAT ARE DATA AND RULE-DRIVEN

2. INCLUDE CODE STRUCTURE ASSESSMENTS AS A FORMAL PART OF DESIGN REVIEWS – FIND MODULES WITH SIMILAR FUNCTIONALITY AND GENERALIZE TO ELIMINATE "DUPLICATES"

3. REVIEW DESIGNS FOR INTERPRETATIONS OF REQUIREMENTS THAT UNNECESSARILY LIMIT ENHANCEMENTS OR EXTENSIONS

4. PERMIT MACHINE DEPENDENCY ONLY WHEN STRONGLY JUSTIFIED

5. DEVELOP AN EVOLUTIONARY ACQUISITION STRATEGY DESIGNED FOR MULTIPLE CYCLES OF DESIGN AND IMPLEMENTATION
RESPONDING TO THE MANAGEMENT CHALLENGE

RETROSPECTIVE ASSESSMENT OF HOW ADAPTATIONS WERE UTILIZED

<table>
<thead>
<tr>
<th>ADAPTATIONS TO ACHIEVE OPERATIONAL EFFECTIVENESS</th>
<th>BFG</th>
<th>ESP</th>
<th>RALPH</th>
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<tr>
<td>1. COMPETING OPS CONCEPTS</td>
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<td>2. USE OF GENERAL REQUIREMENTS</td>
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<td>3. OPS EFFECTIVENESS CRITERIA IN SRR</td>
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<td>4. OPS EFFECTIVENESS CRITERIA IN PDR, CDR</td>
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<td>5. PROTOTYPING PLAN</td>
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<td>6. WORKING SOFTWARE AS SPECIFICATION</td>
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<td>7. BUILD vs BORROW CRITERIA</td>
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<td>8. END-TO-END IMP STRATEGY</td>
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<td>9. OPS EFFECTIVENESS AS TEST CRITERIA</td>
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<td>10. TEST IN OPERATIONAL ENVIRONMENT</td>
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<td>3. PERFORMANCE LIMITATION REVIEWS</td>
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<td>4. MACHINE INDEPENDENCE</td>
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<td>5. EVOLUTIONARY ACQUISITION</td>
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KEY: ● USED  ○ PARTIALLY USED  ○ NOT USED

EVALUATION BASED ON OPERATIONAL EFFECTIVENESS:
- HIGH
- MODERATE
- LOW

EVALUATION SYSTEM BASED ON EXTENSIBILITY:
- HIGH
- LOW
- HIGH

FOCUSING THE TECHNICAL PERSPECTIVE

ADAPTATIONS FOR DOING THE RIGHT JOB EFFICIENTLY

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ADAPTATIONS FOR EASY ACCOMMODATION OF CHANGE

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SUMMARY

- TRADITIONAL PRACTICE OF SYSTEMS ENGINEERING MANAGEMENT ASSUMES REQUIREMENTS CAN BE PRECISELY DETERMINED AND UNAMBIGUOUSLY DEFINED PRIOR TO SYSTEM DESIGN AND IMPLEMENTATION; PRACTICE FURTHER ASSUMES REQUIREMENTS ARE HELD STATIC DURING IMPLEMENTATION

- HUMAN-COMPUTER / DECISION SUPPORT SYSTEMS FOR SERVICE PLANNING AND SCHEDULING APPLICATIONS DO NOT CONFORM WELL TO THESE ASSUMPTIONS

ADAPTATIONS TO THE TRADITIONAL PRACTICE OF SYSTEMS ENGINEERING MANAGEMENT ARE REQUIRED FOR OPERATIONAL EFFECTIVENESS: DOING THE RIGHT JOB EFFICIENTLY FOR EXTENSIBILITY: EASY ACCOMMODATION OF CHANGE

- BASIC TECHNOLOGY EXISTS TO SUPPORT THESE ADAPTATIONS

- ADDITIONAL INNOVATIONS MUST BE ENCOURAGED AND NURTURED

- CONTINUED PARTNERSHIP BETWEEN THE PROGRAMMATIC AND TECHNICAL PERSPECTIVE ASSURES PROPER BALANCE OF THE IMPOSSIBLE WITH THE POSSIBLE
PRESENTATION OUTLINE

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REQUIREMENTS THAT ARE UNLIKE OTHER SYSTEMS

CHARACTERISTIC: THE MERIT OF A PLAN IS DIFFICULT TO QUANTIFY; PLANS USUALLY REPRESENT "ACCEPTABLE COMPROMISES"

QUANTIFIABLE:

\[ \max P = f (\text{START TIME, RESOURCE UTILIZATION, SATISFIED REQUESTS}) \]

NON-QUANTIFIABLE:
• JOE LIKES IT AND HE USED TO DO THE PLANNING
• EVERYBODY CAN LIVE WITH IT
• IT'S OK IF NEXT WEEK THE OTHER USERS CAN HAVE ....
REQUESTMENTS THAT ARE UNLIKE OTHER SYSTEMS

**CHARACTERISTIC:** THE MERIT OF A PLAN IS DYNAMIC

- CIRCUMSTANCES CHANGE
- MERIT MIGHT BE FUNCTION OF HOW THE PLANS LOOK OVER SEVERAL PLANNING HORIZONS

REQUESTMENTS THAT ARE UNLIKE OTHER SYSTEMS

**CHARACTERISTIC:** THE MERIT OF PLAN IS DEPENDENT ON THE PROCESS USED TO GENERATE IT.

- SAME PLAN LOOKS GOOD OR BAD DEPENDING ON NUMBER OF ALTERNATIVES EXAMINED
- MERIT OF PLAN CANNOT BE DETERMINED FROM THE INFORMATION IN THAT PLAN
- MERIT IS PROCESS NOT PRODUCT DEPENDENT
- THIS CHARACTERISTIC IS FUNDAMENTALLY AND CRITICALLY DIFFERENT FROM ENGINEERING SYSTEMS
REQUIREMENTS THAT ARE UNLIKE OTHER SYSTEMS

**CHARACTERISTIC:** THE INFORMATION FLOW CONTENT BETWEEN SERVICE REQUESTER AND THE PLANNER ARE VERY DIFFICULT TO PREDICT

LET C BE THE TOTAL INFORMATION (IN BITS) NEEDED TO RESOLVE THE RESOURCE ALLOCATION; THEN \( N \times B_M = C \).

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REQUIREMENTS THAT ARE UNLIKE OTHER SYSTEMS

**CHARACTERISTIC:** THE TIME REQUIRED TO BUILD A PLAN IS LONGER THAN ORIGINALLY PREDICTED

\[ T_p \text{ IS THE TOTAL PLANNING AND REPLANNING TIME IN HORIZON } K \text{ FOR ACTIVITIES TO OCCUR IN HORIZON } K + 1 \]

\[ H_p \text{ IS THE LENGTH OF THE PLANNING HORIZON} \]

\[ \text{CLEARLY } T_p/H_p < 1 \text{ TO MAINTAIN OPERATIONS} \]

\[ \text{WHAT SHOULD BE THE DESIGN VALUE OF } T_p/H_p? \]
REQUIREMENTS THAT ARE UNLIKE OTHER SYSTEMS

**CHARACTERISTIC:** THE SEQUENCE OF PLANNING TASKS CANNOT BE DETERMINED AT DESIGN TIME

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**GOOD AND BAD STARTING POINTS FOR THE DESIGN**

- DESIGN THE SYSTEM AS A *REPLANNING* SYSTEM
  - REPLANNING IS A MORE FREQUENT TASK IN MOST OPERATIONAL ENVIRONMENTS
  - PLANNING CAN BE ACCOMMODATED AS A SPECIAL CASE OF REPLANNING
  - FIRST COME / FIRST SERVED ALLOCATION (i.e., DEMAND ASSIGNMENT) CAN BE ACCOMMODATED AS A SPECIAL CASE OF PLANNING
GOOD AND BAD STARTING POINTS FOR THE DESIGN

• DESIGN THE SYSTEM INITIALLY TO ALLOW HUMANS TO MAKE ALL DECISIONS
  
  – ALGORITHMS SHOULD BE DESIGNED TO EMULATE HUMAN DECISION BEHAVIOR
  
  – ONLY DECISION MAKING THAT IS DETERMINED TO BE ROUTINE SHOULD BE DELEGATED TO THE MACHINE
  
  – OPERATIONAL EXPERIENCE IS NEEDED TO DETERMINE WHICH DECISIONS ARE ROUTINE

GOOD AND BAD STARTING POINTS FOR THE DESIGN

• DESIGN THE SYSTEM ORIGINALLY TO HANDLE POOLED RESOURCES
  
  – POOLED RESOURCES CAN ACCOMMODATE ANY QUANTITY OF A SHARED RESOURCE
  
  – INDIVIDUAL RESOURCES CAN BE ACCOMMODATED AS A SPECIAL CASE OF POOLED RESOURCES
GOOD AND BAD STARTING POINTS FOR THE DESIGN

- Design the system originally to handle general temporal relationships
  - Accommodate numerous sequence relationships as special cases
    -- Predecessor / successor relationships
    -- Minimum separation
    -- Maximum separation
    -- Minimum overlap
    -- Maximum overlap
    -- Specified overlap
    -- One activity any time during another

PROJECTING THE CONSEQUENCES OF OPERATIONS CONCEPTS

- Understanding our problem domain is very important
  - Example: SNC is *not* primarily
    -- A S/C control center
    -- A communications system
    -- A command and control facility
  SNC *is*
    -- A decision support system
    -- A service planning center
    -- A service provider/facilitator for users
  - The right techniques for the wrong domain won't help

- The design consequences of an operations concept can be predicted
  - Seemingly appropriate concepts can lead to unacceptable costs, complexities, etc.
  - A methodology for predicting the design consequences of an operations concept has been developed
PREDICTING DESIGNS FROM OPERATIONS CONCEPTS:
AN EXAMPLE

OPS CONCEPTS "DIMENSIONS"
- HUMAN/COMPUTER DECISION ROLES
- NUMBER OF USER-TO-SERVICES INTERFACES
- USER-TO-CENTER COMMUNICATION STYLES
- REPLANNING PHILOSOPHY
- REQUEST SATISFACTION GOALS
- USER KNOWLEDGE OF TDRS
- USER KNOWLEDGE OF NETWORK
- SERVICE CONFIRMATION RESPONSE
- RELIABILITY OF SERVICES
- SECURITY OF USERS
- PERCEIVED ABUNDANCE OF RESOURCES
- PERCEIVED COMPLEXITY OF DECISIONS
- DEVELOPMENT vs OPERATIONAL COST TRADEOFFS

SUMMARY

PAST PROBLEMS HAVE THE FOLLOWING ORIGINS:
- NOT RECOGNIZING THE UNUSUAL AND PERVERSE NATURE OF THE REQUIREMENTS (FOR PLANNING AND SCHEDULING)
- NOT RECOGNIZING THE BEST STARTING POINT ASSUMPTIONS (GENERAL CASES) FOR THE DESIGN
- NOT UNDERSTANDING THE TYPE OF SYSTEM THAT WE'RE BUILDING
- NOT UNDERSTANDING THE DESIGN CONSEQUENCES OF THE OPERATIONS CONCEPT SELECTED

THE GOOD NEWS IS THAT WE:
- NOW HAVE MORE SUCCESSFUL SYSTEMS TO EXAMINE
- NOW HAVE A GOOD COLLECTION OF CLASS-LEVEL REQUIREMENTS
- NOW RECOGNIZE THE GENERAL CASES THAT ACCOMMODATE THE REQUIREMENTS FROM A PARTICULAR DOMAIN AS PARAMETRIC SPECIAL CASES
- NOW CAN BEGIN TO PREDICT THE CONSEQUENCES OF OPS CONCEPT ALTERNATIVES