N92-11042

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

PART I: A PROGRAMMATIC PERSPECTIVE

RHODA SHALLER HORNSTEIN

NASA / OFFICE OF SPACE OPERATIONS

PART II: A TECHNICAL PERSPECTIVE

JOHN K. WILLOUGHBY

INFORMATION SCIENCES, INC.

SPACE NETWORK CONTROL CONFERENCE

NASA / GSFC

DECEMBER 12, 1990

-1-

I-1

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,

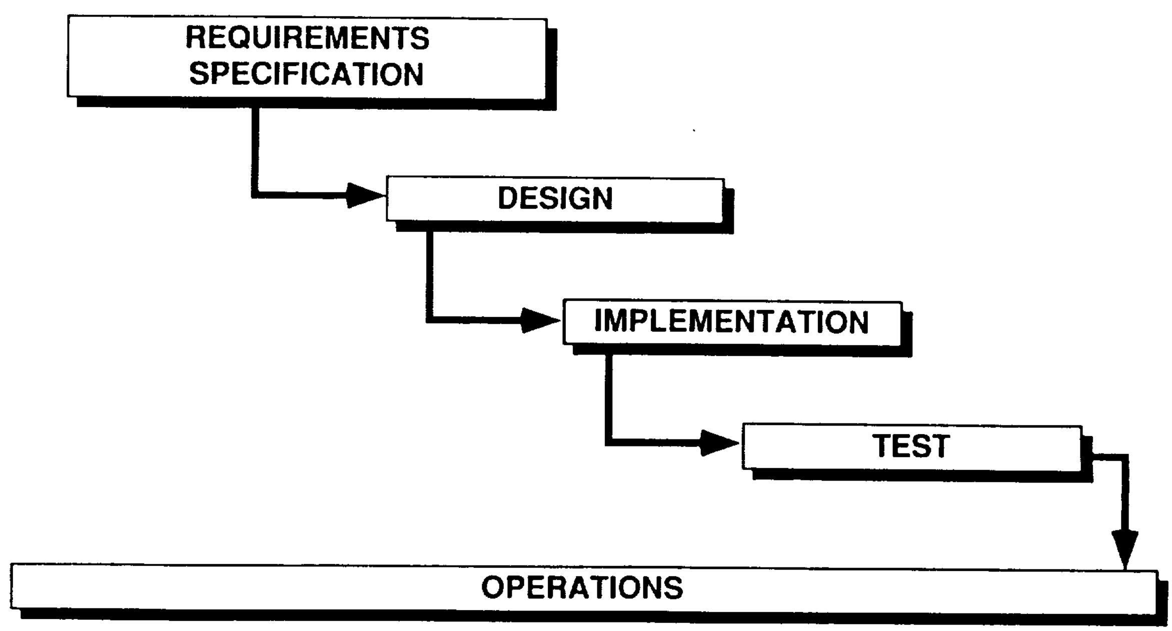
BE ADAPTED, ENHANCED, OR MODIFIED

TO BUILD FUTURE PLANNING AND SCHEDULING SYSTEMS

THAT POSSESS LIFECYCLE EFFECTIVENESS?

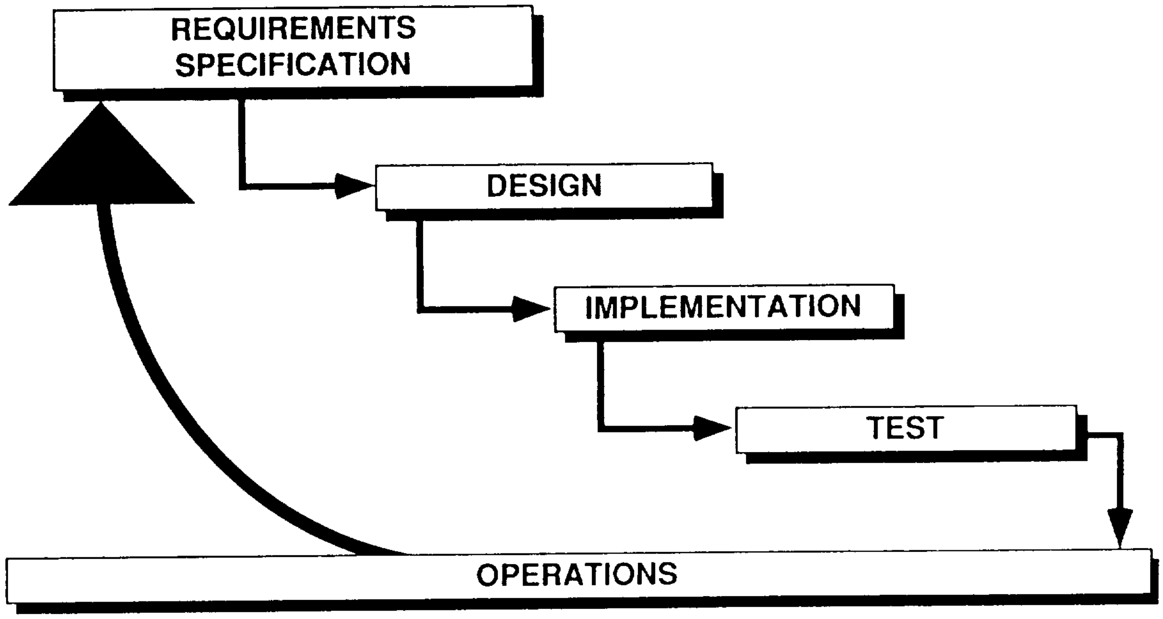
DISSECTING THE MANAGEMENT CHALLENGE

TRADITIONAL SYSTEMS ENGINEERING MANAGEMENT PROCESS



DISSECTING THE MANAGEMENT CHALLENGE

REDESIGNING THE SYSTEM BASED ON OPERATIONAL EXPERIENCE



-5-

E-5

DISSECTING THE MANAGEMENT CHALLENGE

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

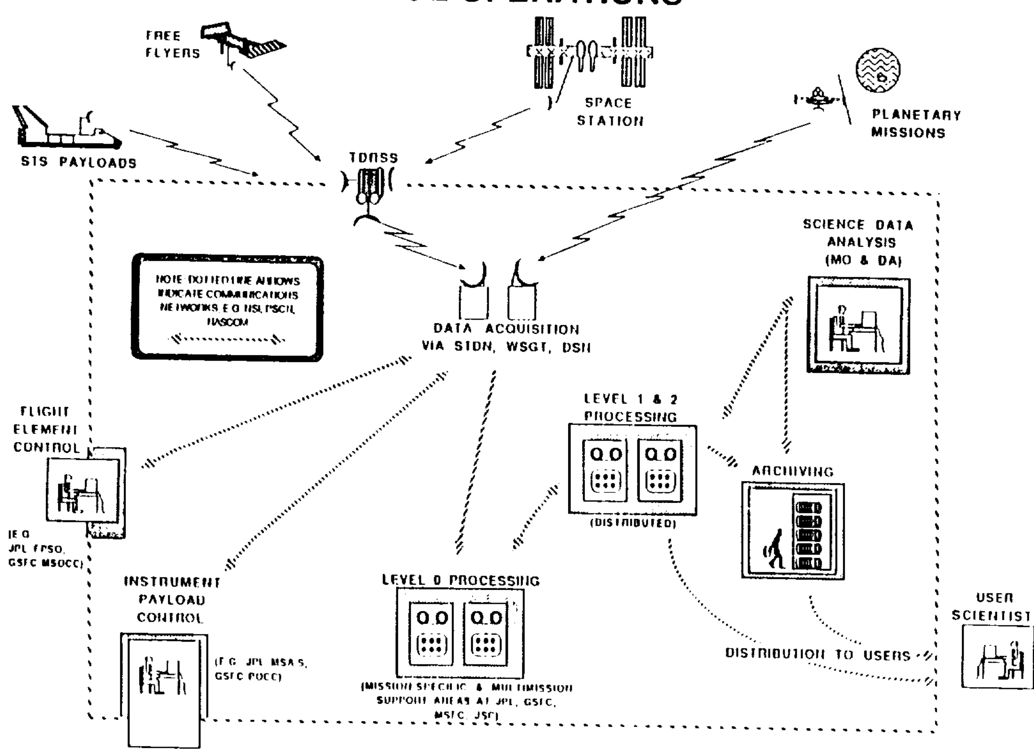
- ACCURATE AND TIMELY ASSIGNMENTS (AND REASSIGNMENTS) OF RESOURCES
- IDENTIFICATION, AVOIDANCE, AND / OR RESOLUTION OF CONFLICTS
- EFFECTIVE AND COMPLEMENTARY HUMAN / COMPUTER INTERACTION
- UNCOMPLICATED AND STRAIGHT FORWARD HUMAN / HUMAN INTERFACE

-6-

E-6

DISSECTING THE MANAGEMENT CHALLENGE

SPACE OPERATIONS



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

9

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

10

I-10

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

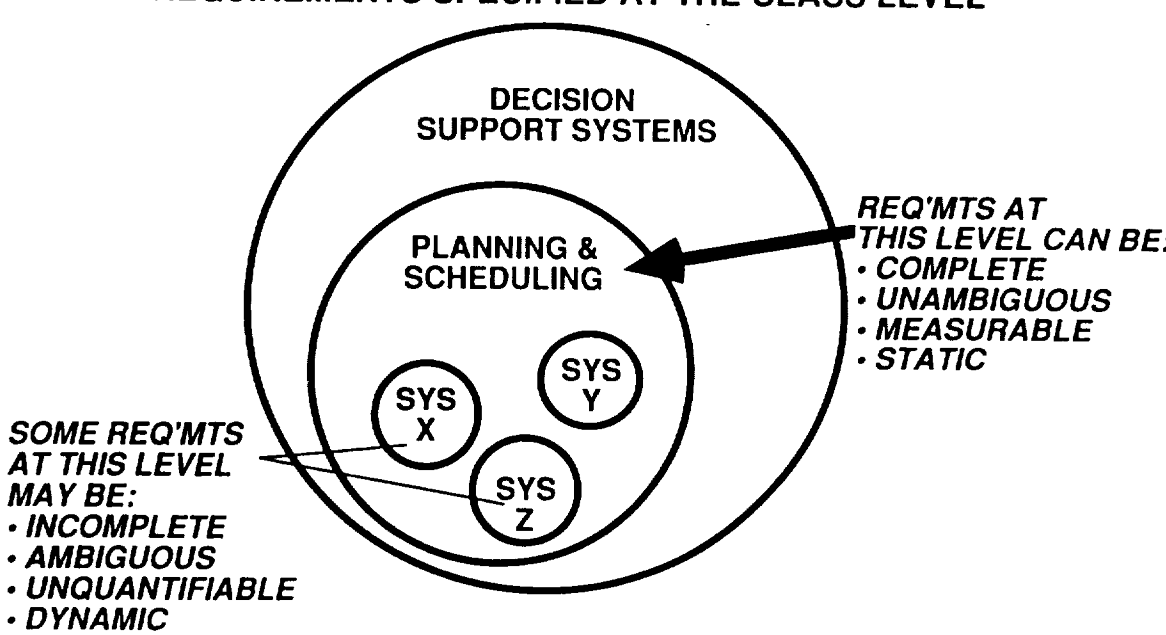
5 ADAPTATIONS ARE RECOMMENDED

-11-

E-11

RESPONDING TO THE MANAGEMENT CHALLENGE

REQUIREMENTS SPECIFIED AT THE CLASS LEVEL



E-12

-12-

RESPONDING TO THE MANAGEMENT CHALLENGE

REQUIREMENTS NEED TO BE ELEVATED

TRANSITION TO A GENERALIZED DESCRIPTION OF PLANNING AND SCHEDULING

FROM	TO
• CREWTIME, POWER, WATER	• RESOURCES
• EXPERIMENT PERFORMANCE	• ACTIVITIES
• SLEEP/ EAT CYCLES	• GENERAL TEMPORAL RELATIONS
INDIVIDUAL SYSTEM LEVEL	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

	ADAPTATIONS TO ACHIEVE OPERATIONAL EFFECTIVENESS	BFG	ESP	RALPH
1	COMPETING OPS CONCEPTS	○	UNK	●
2	USE OF GENERAL REQUIREMENTS	◐	◐	◐
3	OPS EFFECTIVENESS CRITERIA IN SRR	●	UNK	◐
4	OPS EFFECTIVENESS CRITERIA IN PDR, CDR	●	UNK	◐
5	PROTOTYPING PLAN	◐	◐	●
6	WORKING SOFTWARE AS SPECIFICATION	●	UNK	◐
7	BUILD vs BORROW CRITERIA	○	UNK	◐
8	END-TO-END IMP STRATEGY	●	◐	●
9	OPS EFFECTIVENESS AS TEST CRITERIA	●	UNK	○
10	TEST IN OPERATIONAL ENVIRONMENT	●	◐	●
	ADAPTATIONS TO ACHIEVE EXTENSIBILITY	**BFG**	**ESP**	**RALPH**
1	DATA- AND RULE-DRIVEN	●	○	●
2	CODE STRUCTURE ASSESSMENTS	●	UNK	●
3	PERFORMANCE LIMITATION REVIEWS	●	○	●
4	MACHINE INDEPENDENCE	◐	◐	◐
5	EVOLUTIONARY ACQUISITION	●	◐	●

KEY: ● USED ◐ PARTIALLY USED ○ NOT USED

	BFG	ESP	RALPH
EVALUATION BASED ON OPERATIONAL EFFECTIVENESS	HIGH	MODERATE	HIGH
EVALUATION SYSTEM BASED ON EXTENSIBILITY	HIGH	LOW	HIGH

FOCUSING THE TECHNICAL PERSPECTIVE

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

FOCUSING THE TECHNICAL PERSPECTIVE

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

-17-

E-17

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

-18-

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

REQUIREMENTS THAT ARE UNLIKE OTHER SYSTEMS

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

QUANTIFIABLE:

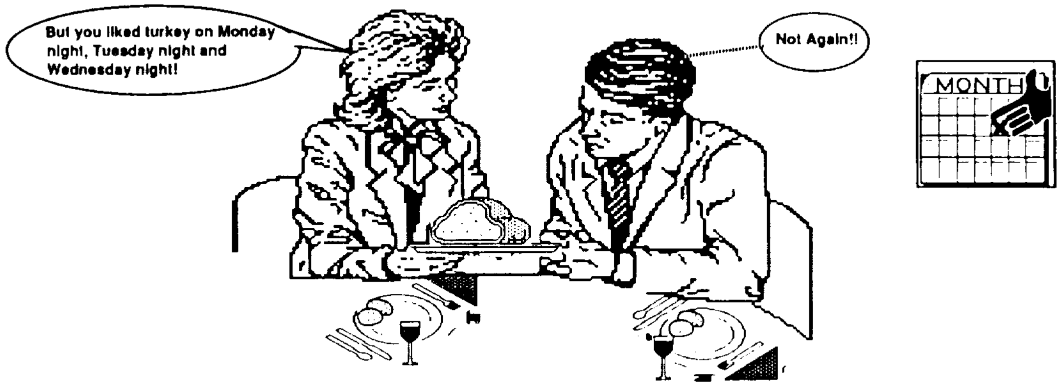
MAX **P** = **f** (START TIME, RESOURCE UTILIZATION, SATISFIED REQUESTS)

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 . . . .

REQUIREMENTS THAT ARE UNLIKE OTHER SYSTEMS

CHARACTERISTIC: THE MERIT OF A PLAN IS DYNAMIC

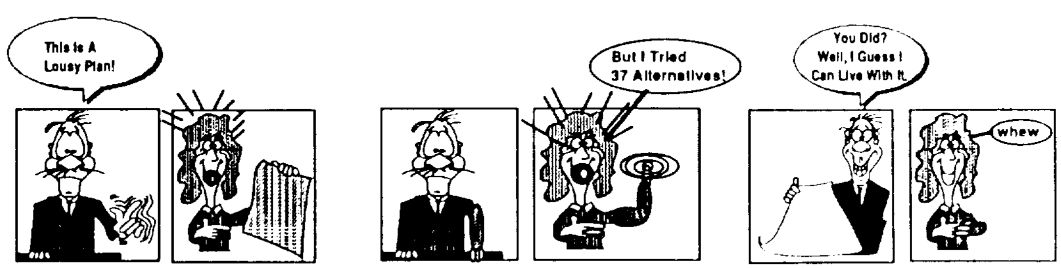


- CIRCUMSTANCES CHANGE

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

REQUIREMENTS THAT ARE UNLIKE OTHER SYSTEMS

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



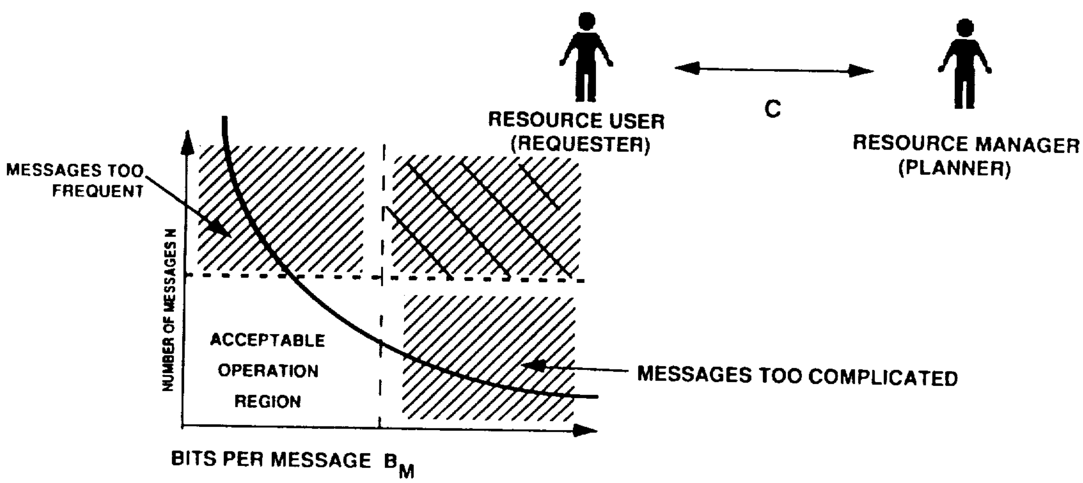
NO INFORMATION ABOUT PROCESS — PROCESS INFORMATION PROVIDED — MERIT OF THE PLAN "CHANGES"

- 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

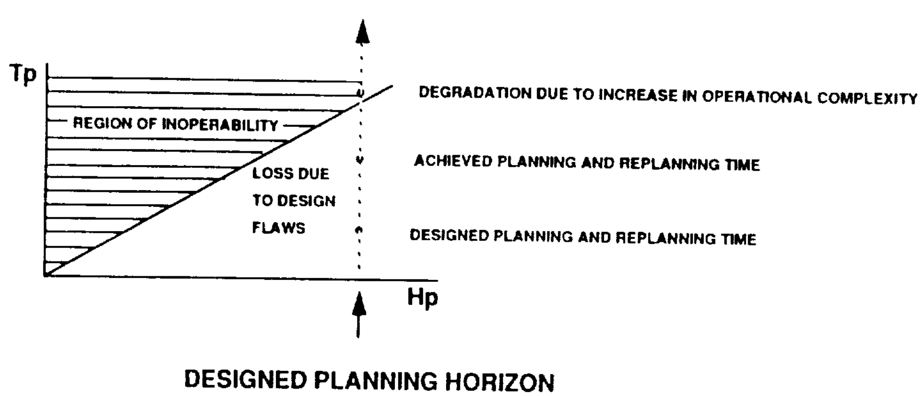
CHARACTERISTIC: THE INFORMATION FLOW CONTENT BETWEEN SERVICE REQUESTER AND THE PLANNER ARE VERY DIFFICULT TO PREDICT

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



REQUIREMENTS THAT ARE UNLIKE OTHER SYSTEMS

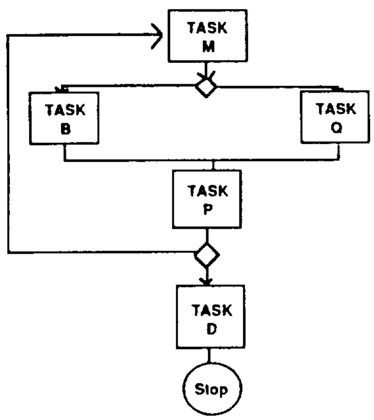
CHARACTERISTIC: THE TIME REQUIRED TO BUILD A PLAN IS LONGER THAN ORIGINALLY PREDICTED



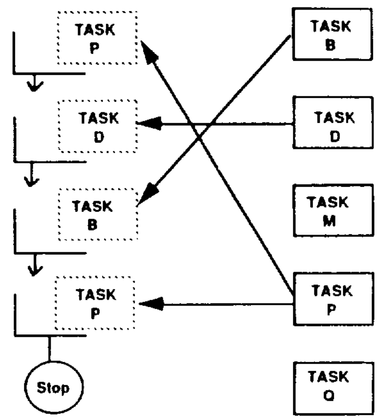
- Tp IS THE TOTAL PLANNING AND REPLANNING TIME IN HORIZON K FOR ACTIVITIES TO OCCUR IN HORIZON K + 1
- Hp IS THE LENGTH OF THE PLANNING HORIZON
- CLEARLY Tp/Hp < 1 TO MAINTAIN OPERATIONS
- WHAT SHOULD BE THE DESIGN VALUE OF Tp/Hp?

REQUIREMENTS THAT AT ARE UNLIKE OTHER SYSTEMS

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



TASK SEQUENCE DETERMINABLE AT DESIGN TIME



TASK SEQUENCE DETERMINABLE AT TASK PERFORMANCE TIME

-25-

E-25

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

E-27

-27-

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

-29-

E-29

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

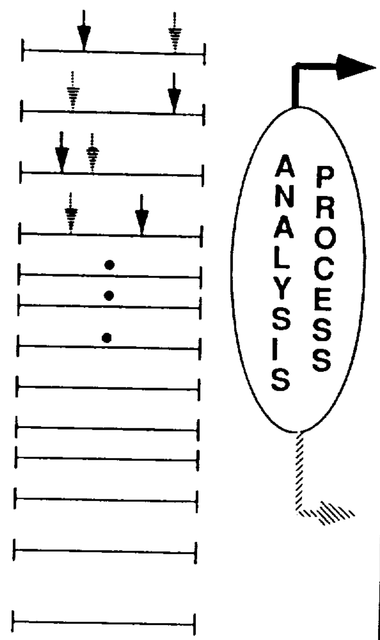
-30-

E-30

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



- USE DIGITAL MSG'S FOR COMM
- FAULT ISOLATION IN NCC
- SCHEDULE BY PRIORITY
- FEED SERVICE ACCT'G BACK TO SCHEDULER PERIODICALLY
- .

- USE FAX & E-MAIL FOR COMM
- FAULT ISOLATION IN NCC
- SCHEDULE BY COMBINATION OF CRITERIA
- FEED SERVICE ACCT'G BACK TO SCHEDULER IN SAME PLANNING CYCLE
- .

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