CONTROL OF FLIGHT SOFTWARE DEVELOPMENT COSTS

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PROBLEM

SOFTWARE IS EXPENSIVE

SCHEDULES ARE DIFFICULT TO PREDICT AND TO MEET

COST AND SCHEDULE OVERRUNS ARE COMMON

FUTURE PROGRAMS WILL BE 10 TIMES LARGER THAN PAST PROGRAMS

HOW CAN SOFTWARE COSTS BE KEPT UNDER CONTROL?

TYPICAL PROGRAMMING PROBLEM AREAS

COORDINATION OF SOFTWARE EFFORT

SOFTWARE SPECIFICATIONS

SCHEDULES

MACHINE RESOURCES (FIXED AND ERASABLE MEMORY)

CODING DIFFICULTIES (FIXED POINT, LACK OF COMPILER, ETC.)

ERASABLE MANAGEMENT

RESTART PROTECTION

VERIFICATION TESTING

COMMUNICATION OF CRITICAL DATA

DEFINITION OF INTERFACES

DOCUMENTATION

CONFIGURATION CONTROL

SOLUTIONS

DEVELOP COMPREHENSIVE MANAGEMENT PLAN

DEFINE MAJOR PROBLEM AREAS

SPECIFY TOOLS AND TECHNIQUES REQUIRED TO MAINTAIN CONTROL OVER SOFTWARE DEVELOPMENT

SOFTWARE MANAGEMENT PLAN

IDENTIFY KEY ELEMENTS OF SOFTWARE DEVELOPMENT

DEFINE INTER-RELATIONSHIPS AMONG THESE ELEMENTS

DEFINE MAJOR PROBLEM AREAS

IDENTITY REQUIRED TOOLS AND TECHNIQUES

KEY ELEMENTS OF SOFTWARE DEVELOPMENT

TRANSLATION OF TOP LEVEL MISSION REQUIREMENTS INTO SOFTWARE REQUIREMENTS AND ORGANIZATION

SOFTWARE ANALYSIS, DESIGN, AND SPECIFICATION

CODE GENERATION

SOFTWARE VERIFICATION

DOCUMENTATION

CONFIGURATION CONTROL

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HARDWARE AND SOFTWARE SPECIFICATION

SPECIFY HARDWARE AND SOFTWARE TO MINIMIZE COST OF CODE GENERATION AND VERIFICATION

UTILIZE RADICAL SIMPLIFICATION OF HARDWARE AND SOFTWARE STRUCTURE, IF NECESSARY, TO CONTROL COSTS

SPECTRUM OF SOFTWARE STRUCTURES

MOST COMPLEX

1. GENERAL PURPOSE STRUCTURE

   OPERATING SYSTEM (ACCESS METHODS, RESOURCE ALLOCATION, ETC)
   MULTIPROGRAMMED JOB SCHEDULING
   INTERRUPTS

2. AGC STRUCTURE

   NO OPERATING SYSTEM
   MULTIPROGRAMMED JOB SCHEDULING
   INTERRUPTS

3. PSEUDO BATCH-MODE STRUCTURE (STS TASK 5)

   SHORT JOB SEGMENTS
   BATCH SCHEDULING OF JOBS
   NO INTERRUPTS

4. POINTER DRIVEN STRUCTURE (POSEIDON)

   NO MULTIPROGRAMMING
   DETERMINISTIC PROGRAM SEQUENCING

LEAST COMPLEX

EXAMPLE I: GENERAL PURPOSE STRUCTURE

ADVANTAGES

EXPERIENCE WITH GROUND BASED SYSTEMS
EXTENSIVE LOGICAL SWITCHING AND SUPERVISORY CAPABILITY

DISADVANTAGES

VERY EXPENSIVE TO GENERATE AND TO VERIFY CODE
COMPLEX OPERATING SYSTEM IS INAPPROPRIATE TO A WELL DEFINED APPLICATION
DIFFICULT TO SPECIFY
COST LIKELY TO GET OUT OF CONTROL

EXAMPLE 2: AGC PROGRAM STRUCTURE

ADVANTAGES

IDEAL FOR MACHINE WITH:

- LIMITED RESOURCES (TIME, MEMORY, ETC.)
- SHORT RESPONSE TIME REQUIREMENTS
- NO SUBSYSTEM COMPUTATIONAL CAPABILITY

MODERATE COST FOR CODE GENERATION **AND** VERIFICATION
FLEXIBLE PROGRAM STRUCTURE
MODULAR PROGRAM ELEMENTS
EASILY SPECIFIABLE

DISADVANTAGES

INTERRUPTS REQUIRED
MULTIPROGRAMMED SYSTEM IS EXPENSIVE TO VERIFY
DIFFICULT TO PREVENT INTERACTION BETWEEN COMPETING JOBS

EXAMPLE 3: PSEUDO BATCH-MODE STRUCTURE (STS TASK 5)

ADVANTAGES

HIGHLY SIMPLIFIED SOFTWARE STRUCTURE
NO INTERRUPTS OR MULTIPROGRAMMING
SIMPLIFIES PROGRAM SPECIFICATION
PROMOTES MODULARITY OF PROGRAMS
ALLOWS SPECIFICATION OF RESOURCES BY:

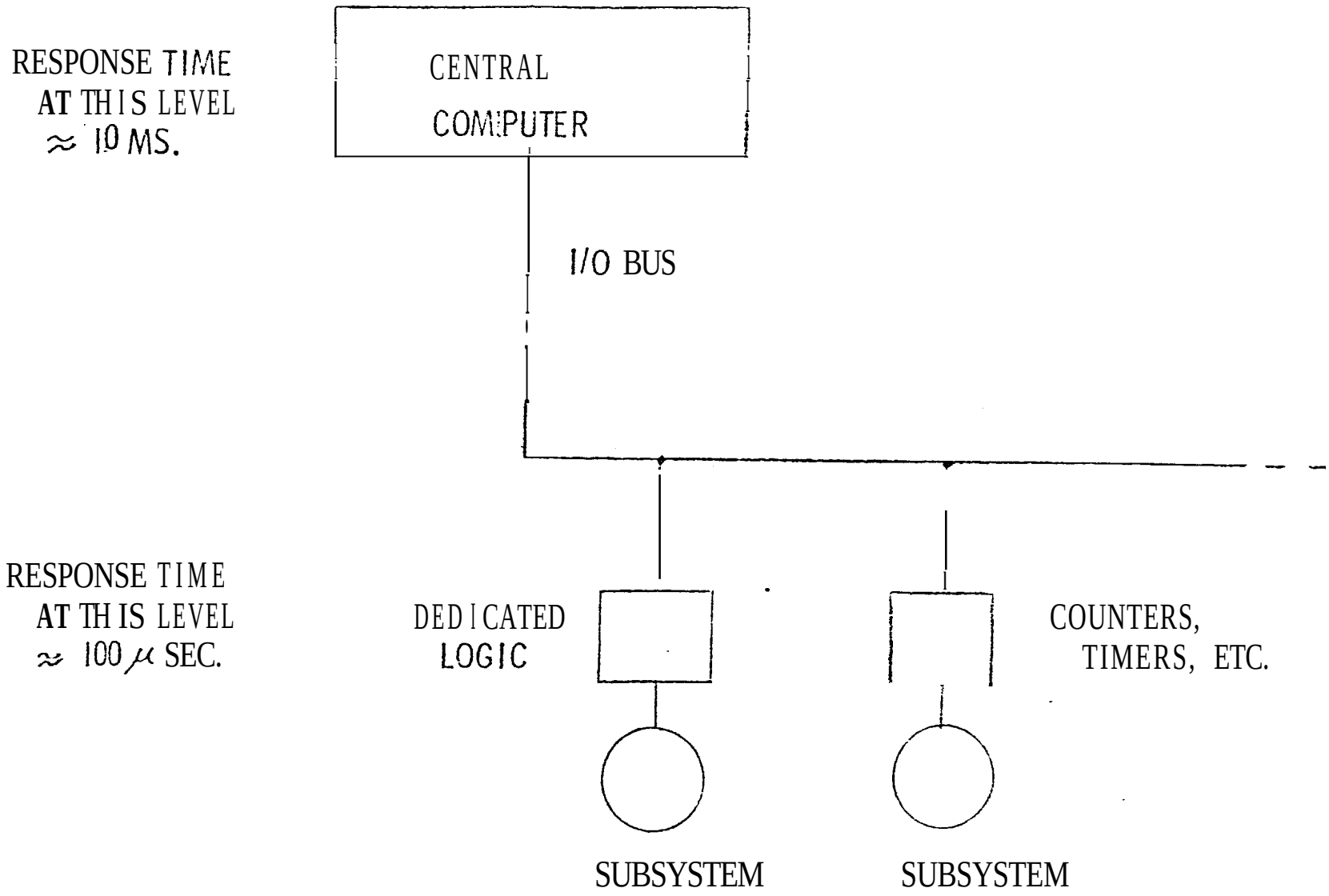
- CPU TIME
- SYSTEM RESPONSE

JOBS ARE RUN AS DECOUPLED SEGMENTS - MINIMAL INTERACTION
SIMPLIFIED SUB SYSTEM SELL-OFF PROCEDURE

- RUN RELEVANT SUBSYSTEM MODULES
- SIMULATE LOAD OF OTHER SUBSYSTEM JOB SEGMENTS

DISADVANTAGES

PREPROCESSING REQUIRED AT SUBSYSTEM LEVEL-
SYSTEM RESPONSE TIME IS RELATIVELY SLOW
JOBS MUST BE SEGMENTED


RESPONSE TIME
AT THIS LEVEL
≈ 10 MS.
CENTRAL
COMPUTER
I/O BUS
RESPONSE TIME
AT THIS LEVEL
≈ 100 μ SEC.
DEDICATED
LOGIC
COUNTERS,
TIMERS, ETC.
SUBSYSTEM
SUBSYSTEM

PSEUDO BATCH-MODE STRUCTURE	APOLLO STRUCTURE
LIMITED SUBSYSTEM LOGICAL CAPABILITY	NO SUBSYSTEM LOGICAL CAPABILITY
FLOATING POINT	NO FLOATING POINT
HARDWARE RESTART PROTECTION	SOFTWARE RESTART PROTECTION
MICROPROGRAMMABLE OP-CODES	FIXED OP-CODE REPERTOIRE
TEST-COOPERATIVE HARDWARE	NON TEST-COOPERATIVE HARDWARE
MINIMAL INTERRUPTS	EXTENSIVE INTERRUPTS
COMPILER	ASSEMBLER/INTERPRETER
NO MULTIPROGRAMMING	MULTIPROGRAMMING
MINIMAL EXECUTIVE	MODERATE EXECUTIVE
MINIMAL PRIORITY STRUCTURE	EXTENSIVE PRIORITY STRUCTURE

Figure 3 Comparison Between Pseudo Batch-Mode Structure and Apollo Structure

HARDWARE SPECIFICATION	APOLLO PROBLEM SOLVED
FAST CPU	COMPUTATIONAL OVERLOAD REDUCED
FLOATING POINT	ELIMINATE FIXED POINT OPERATIONS
SPECIALIZED OP-CODES FOR VECTOR-MATRIX MANIPULATION	ELIMINATE INTERPRETIVE OPERATIONS
MICROPRAMMED OP-CODES	DELAY DETAILED MACHINE SPECIFICATION
SINGLE INSTRUCTION RESTART	ELIMINATE SOFTWARE RESTART PROBLEMS
ADEQUATE MEMORY LONGER WORD LENGTH	GREATER PRECISION, FEWER DOUBLE AND TRIPLE PRECISION COMPUTATIONS
ADEQUATE ERASABLE MASS MEMORY	REDUCE ERASABLE CONFLICTS REMOVE LIMIT ON GROWTH OF MEMORY
TEST-COOPERATIVE FEATURES	REDUCE VERIFICATION COST AND IMPROVE CONFIDENCE IN FLIGHT CODE

EXAMPLE 4: POINTER DRIVEN SOFTWARE STRUCTURE - POSEIDON COMPUTER

ADVANTAGES

STATE OF MACHINE DEFINED BY SET OF POINTERS

NO OPERATING SYSTEM

NO INTERRUPTS - GREATLY SIMPLIFIES VERIFICATION

STRUCTURE EMPHASIZES MODULARITY

EASILY SPECIFIED FUNCTIONS

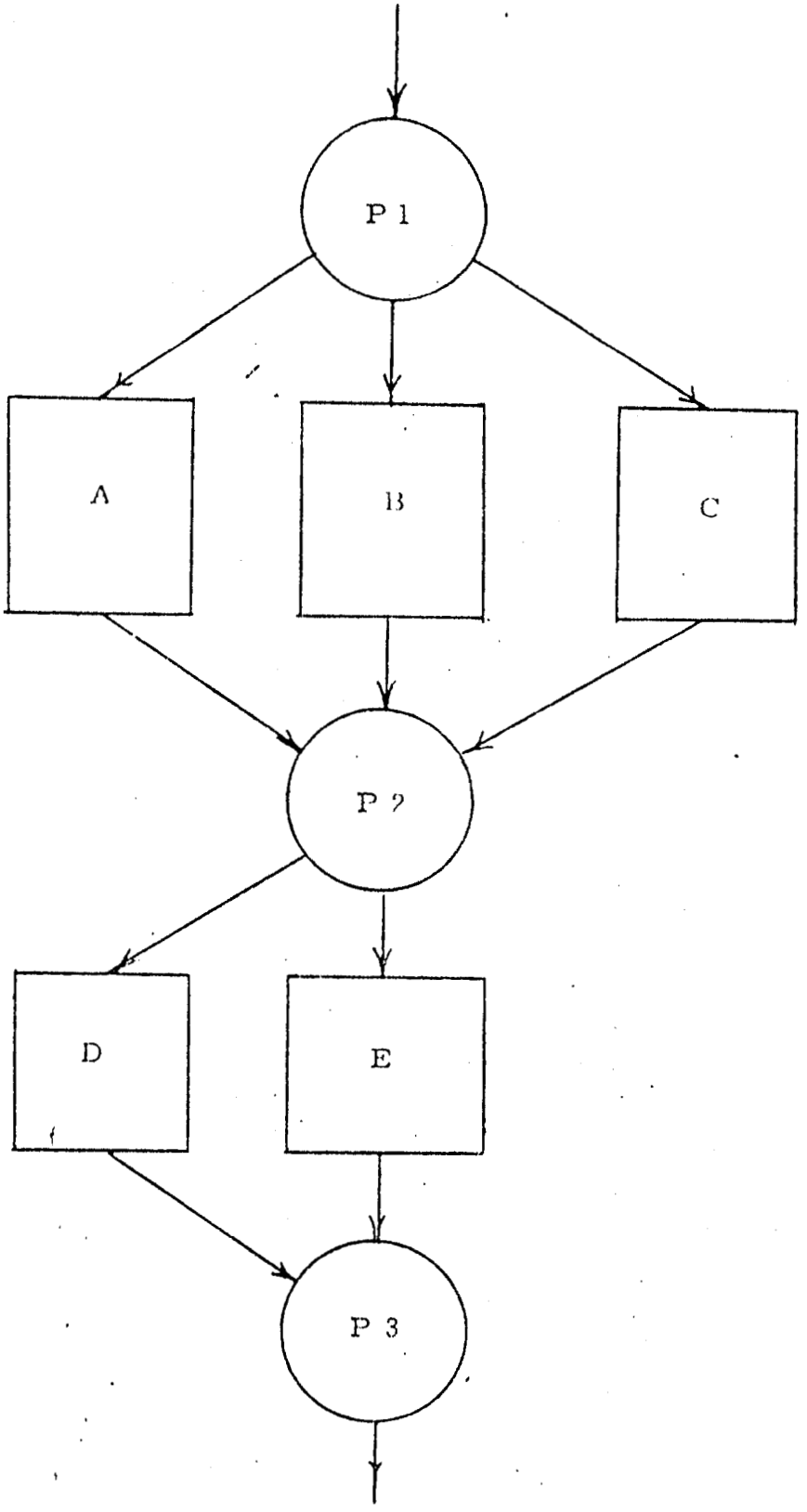
STRUCTURE LENDS ITSELF TO STATIC VERIFICATION

DISADVANTAGES

LESS FLEXIBLE THAN APOLLO

REQUIRES STRUCTURED SEQUENCING

BEST FOR DETERMINISTIC SYSTEMS (LOCAL PROCESSORS, ACE, OR UNMANNED MISSIONS)



Pointer 1

Level 1 Program;

Pointer 2

Level 2 Program:

Pointer 3

Etc.

Figure 4 Pointer Driven Software Structure

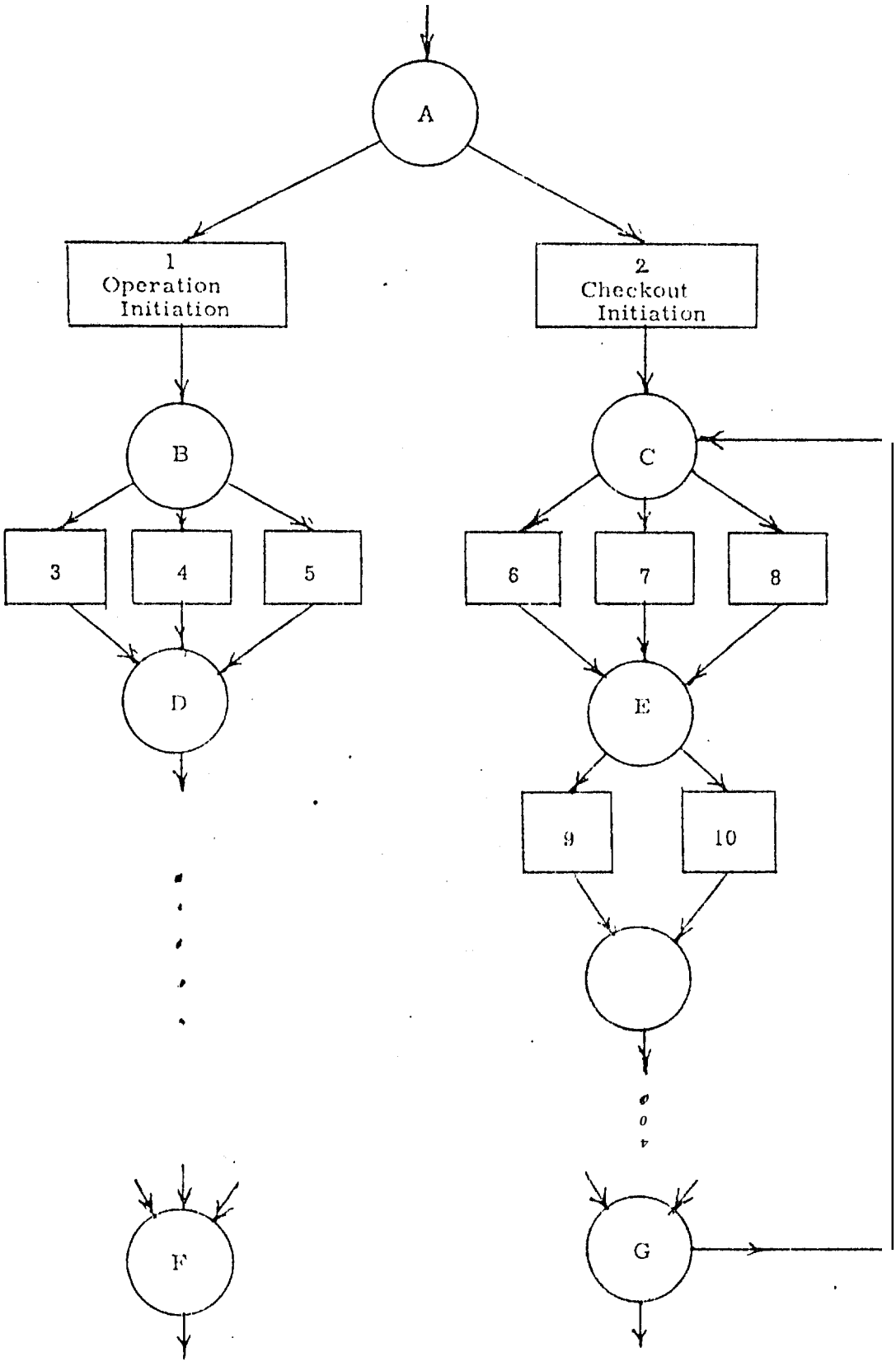


Figure 5 Example of Software Structure

RECOMMENDED TOOLS AND TECHNIQUES

COMPILER AND METACOMPILER

AUTOMATED FLIGHT COMPUTER VERIFICATION FACILITY

INTERACTIVE PROGRAM DEVELOPMENT AND VERIFICATION TECHNIQUES

SELF-CONTAINED AUTOMATED CHECKOUT FACILITJES IMBEDDED IN FLIGHT SOFTWARE

COMPREHENSIVE STATIC VERIFICATION TECHNIQUES

SELF-DOCUMENTATION

MODELLING TOOL TO **EVALUATE** SOFTWARE STRUCTURES

COMPILER

ESTABLISH CONTINUITY BETWEEN GUIDANCE ANALYSTS AND FLIGHT COMPUTER PROGRAMMERS

REDUCE COST OF CODE GENERATION

PERFORM STATIC VERIFICATION

ENFORCE PROGRAMMING CONVENTIONS

PROVIDE SELF-DOCUMENTATION OF CODE

REDUCE DEPENDANCY OF CODE ON MACHINE ARCHITECTURE

AUTOMATED FLIGHT COMPUTER VERIFICATION FACILITY

EST-COOPERATIVE FLIGHT COMPUTER LINKED TO GENERAL PURPOSE COMPUTER

COMMON FACILITY FOR PROCEDURAL SIMULATIONS AND DIGITAL SIMULATIONS

DETAILED DIAGNOSTIC CAPABILITY

STATE OF MACHINE CONTINUOUSLY RECORDED

RERUN CAPABILITY

INTERACTIVE PROGRAM DEVELOPMENT AND VERIFICATION

INEXPENSIVE TV DISPLAY FACILITY ($5,700 PER TERMINAL)

CONTROLLED ACCESS TO COMMON DATA BASE

INTERACTIVE TECHNIQUES FOR:

- DEVELOPMENT PLAN
- GUIDANCE ALGORITHM DEVELOPMENT
- FLIGHT PROGRAMMING
- SIMULATION INPUT AND EDITED OUTPUT
- MAINTAINANCE OF PROGRAMS

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