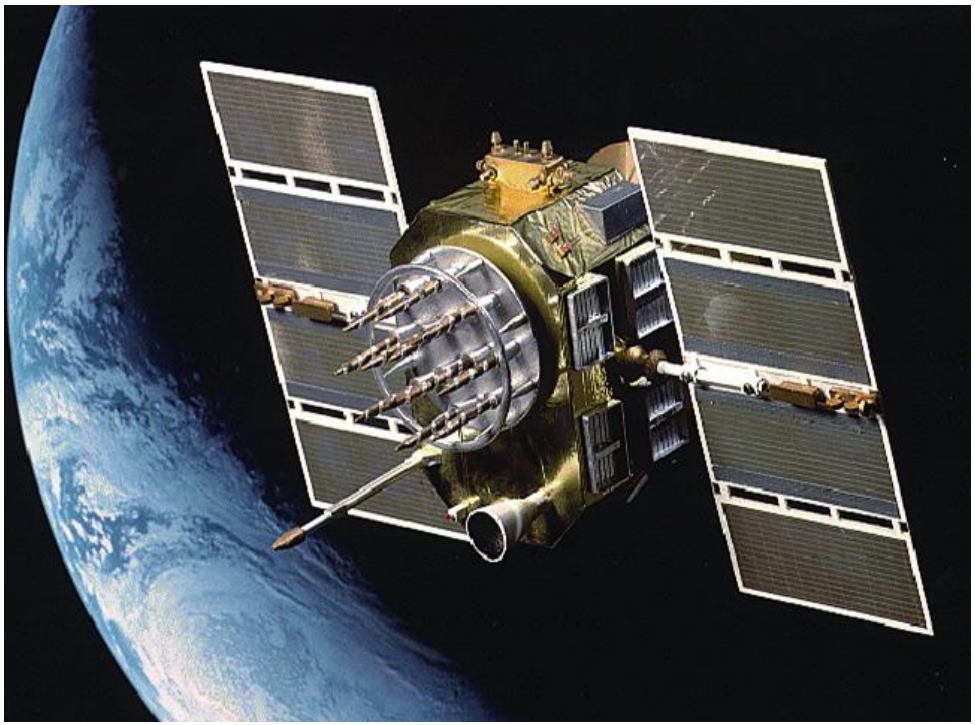
Global Positioning System (GPS) Systems Engineering (SE) Case Study



Randy Bullard
AFIT/SYA
25 Oct 2007

Agenda

- Why SE Case Studies Are Important
- Example – GPS
  - Method of Analysis
  - Results
  - Benefits (Education & Practice)
- Foundational SE Learning Principles
- Summary

Why We Do Case Studies

AF CSE

- AF Center for SE tasked to develop case studies
  - Focus on application of SE principles in various programs

- Additional case studies
  - Completed:
    - C-5
    - F-111
    - Hubble Telescope
    - Theatre Battle Management Core System (TBMCS)
    - B-2
    - Joint Air to Surface Standoff Missile (JASSM)
  - In work: A-10 & Peacekeeper
  - More on contract in FY08

Case Study Construct

- Support teaching & practicing of SE principles
  - Facilitate learning by emphasizing long-term consequences of SE & programmatic decisions on program success
  - Provide real-world, detailed examples of how SE process attempts to balance cost, schedule, & performance
- Used Friedman-Sage framework & matrix for analysis
- Identify learning principles
  - Discuss factors that significantly influenced successful outcome and failures of the program

SE processes used in today's complex system and system-of-systems were matured and founded on principles developed in the past.

Friedman-Sage Framework

- Developed by:
  - Dr George Friedman: University of Southern California
  - Dr Andy Sage: George Mason University
- Comprised of 9 concept domains (rows) & 3 responsibility domains (columns)
  - Rows represent phases in SE life cycle & necessary process and systems management support
  - Columns depict responsibilities from both sides of the program (industry and government)
- Derived into matrix
  - Identifies learning principles
- Used as analysis baseline

Friedman-Sage Matrix

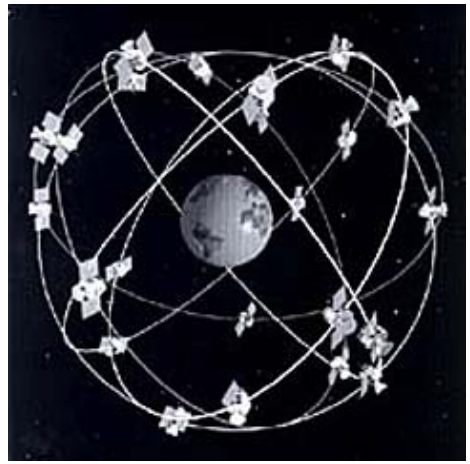
	Concept Domain	Responsibility Domain		
		1. Contractor Responsibility	2. Shared Responsibility	3. Government Responsibility
A.	Requirements Definition and Management			LP 3
B.	Systems Architecture and Conceptual Design			
C	System and Subsystem Detailed Design and Implementation			
D.	Systems Integration and Interface			LP 2
E.	Validation and Verification			
F.	Deployment and Post Deployment			
G.	Life Cycle Support			
H.	Risk Assessment and Management		LP 4	
I.	System and Program Management		LP 1	

GPS Program Background

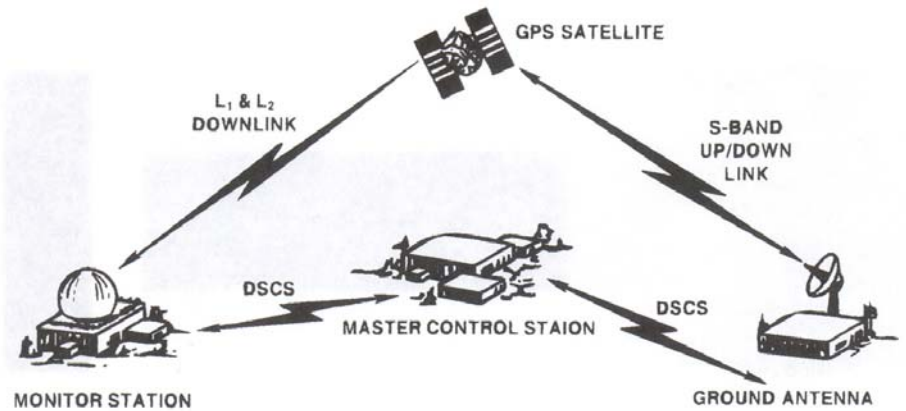
- Russians launched Sputnik, 1957
  - Satellite circled earth broadcasting its tone
  - US engineer postulated using Doppler Effect
    - Orbiting satellite could compute location on Earth
  - Air Force & Navy established separate programs
    - They demonstrated many key technologies
- DoD established Joint Program Office (JPO), 1972
  - Purpose was to replace land-based navigation aids
  - Air Force was assigned to lead JPO
    - Joint effort included Army, Navy, & Coast Guard
  - JPO tasked to develop space-based navigation system

GPS System

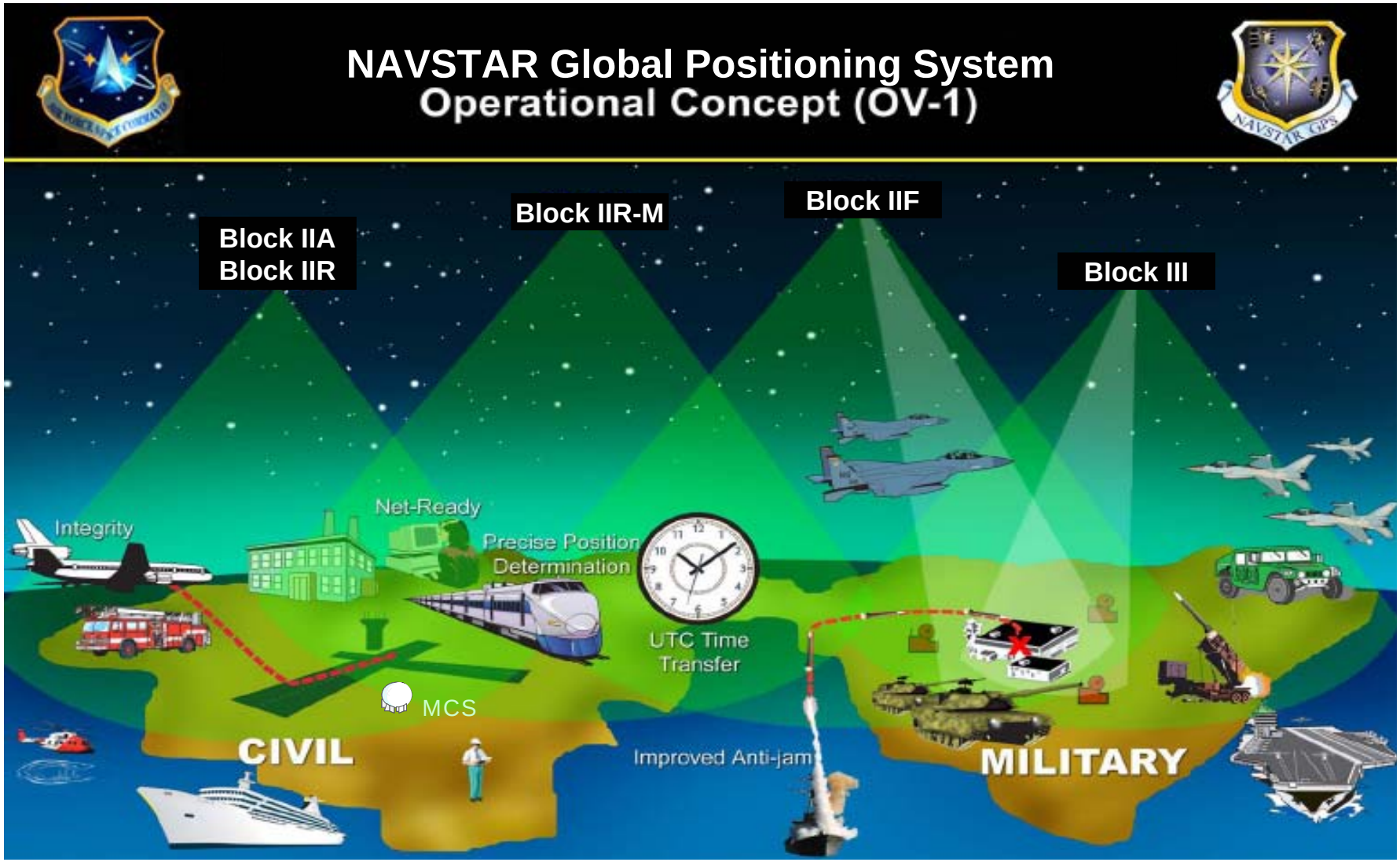
- System requirements
  - Accurate
  - Global
  - Real-time
  - Continuous
  - Additional characteristics



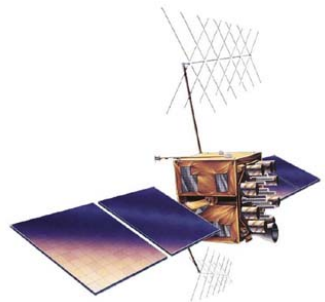
- System design
  - Space Vehicle (SV)
  - User Equipment (UE)
  - Control Station (CS)



GPS OV-1


NAVSTAR Global Positioning System
Operational Concept (OV-1)
Block IIA
Block IIR
Block IIR-M
Block IIF
Block III
Integrity
Net-Ready
Precise Position
Determination
UTC Time
Transfer
MCS
CIVIL
Improved Anti-jam
MILITARY

GPS SE Approach



- JPO constructed system specification
  - It became the functional baseline
  - Strategy was to manage:
    - Requirements at the performance level
    - Interfaces between space vehicles, control stations, & users
  - Process highlighted cost, schedule, & performance risks
    - Impacted team derived alternatives
    - Decisions made quickly by management
- Program placed emphasis on staffing key positions
  - JPO staffed with technical officers & civilians
  - Aerospace augmented with engineering & scientific staff

Learning Principles

1. Programs must strive to staff key positions with domain experts
2. The systems integrator must rigorously maintain program baselines
3. Achieving consistent and continuous high-level support and advocacy helps funding stability, which impacts SE stability
4. Disciplined and appropriate risk management must be applied throughout the lifecycle

Learning Principle 1

Programs must strive to staff key positions with domain experts

- Program personnel were well-versed in their disciplines
  - All possessed a systems view of the program
  - Entire team understood implications of their work at all system levels
- They used a knowledge-based approach for decision making
  - Information was understood and the base and alternative solutions were accurately presented.
  - This shortened the decision cycle
- Additional benefits were realized
  - Communications were better
  - Working relationships were improved

Learning Principle 2

The systems integrator must rigorously maintain program baselines

- JPO retained the role of managing and controlling the systems specification
  - This allowed control of functional baseline
- They derived and constructed an “agreed-to” set of systems requirements that became the program baseline
  - Performance/Risk/Cost trade studies against functional baseline used to control both risk and cost
  - Interface Control Working Group process managed the functional requirements on the allocated baseline
  - Processes gave JPO first-hand knowledge and insight into risks at lowest level

Learning Principle 3

Achieving consistent and continuous high-level support and advocacy helps funding stability, which impacts SE stability

- OSD support provided requirements and funding stability
  - They provided advocacy and sourced funding at critical times
  - They catalyzed coordination among the various services
  - They reviewed & approved GPS JPO system requirements
- OSD played the central role in the establishment and survivability of the program
  - They had support from Deputy Secretary of Defense
- Military services were primary users & eventual customers
  - Each service initially advocated their individual programs
  - SECAF supplied manpower & facilities

Learning Principle 4

Disciplined and appropriate risk management must be applied throughout the lifecycle

- GPS program structured to address risk throughout the multiphase program
- Key risks were known up front
  - Contractor and/or government utilized a classic risk approach to identify & analyze risk
  - They developed and tracked mitigation actions
  - Various risks (design, manufacturing, launch) were managed by office who owned those risks
- Technical risks tracked by Technical Performance Measures (TPMs)
  - Satellite weight & SLOC were tracked
  - TPMs addressed at weekly chief engineer's meetings

SE Outcomes

- SE played major role in GPS success
  - Identifying system requirements
  - Integrating new technologies
  - Taking system of systems approach
  - Interfacing with many government & industry agencies
  - Dealing with lack of an operational user early in program formation

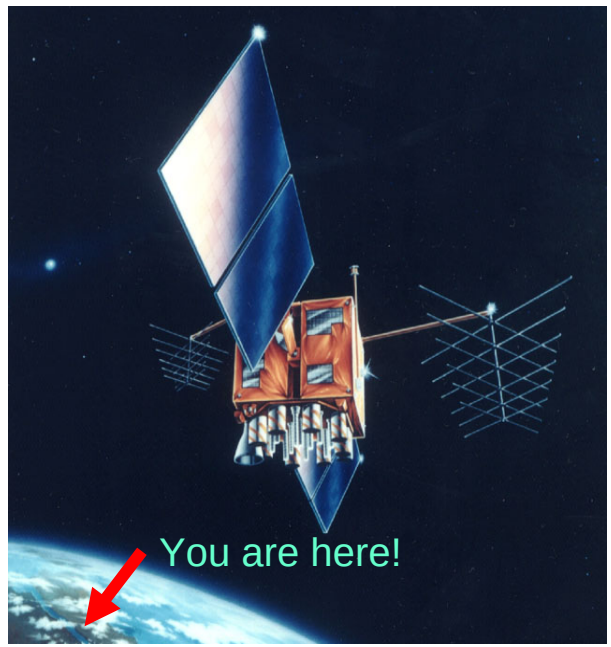
- Key learning principles identify SE processes
  - Application of SE processes is required throughout life cycle
  - Experienced people applying sound SE principles, practices, processes, & tools are necessary at each phase

GPS Program Success

- JPO overcame numerous challenges:
  - Technology, customers, organization, cost, & schedule
  - Integrating new technologies

- Program achieved great success
  - Military relied upon extensively
  - Civilian applications growing
  - Unique uses invented

Imagine current technology without GPS!

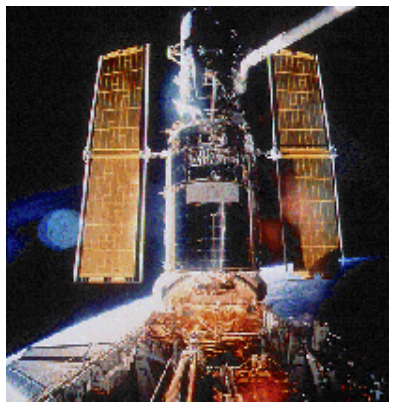


CSE Case Studies

Case studies on our website:

http://www.afit.edu/cse/cases.cfm

B-2



Hubble

F-111

C-5

TBMCS

Questions ?

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