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GPS Modernization

ATCA Symposium

Washington, D.C.

15 January 2002

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Overview

- GPS Program Introduction - Who we are
- Constellation Status - Where we are now
- Civil Signal Modernization - What we are doing
- Ground Augmentation - What else is helping
- GPS III Program - When we get there
- Summary - Why you should care

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Overview

- **GPS Program Introduction**
- **Constellation Status**
- **Civil Signal Modernization**
- **Ground Augmentation**
- **GPS III Program**
- **Summary**

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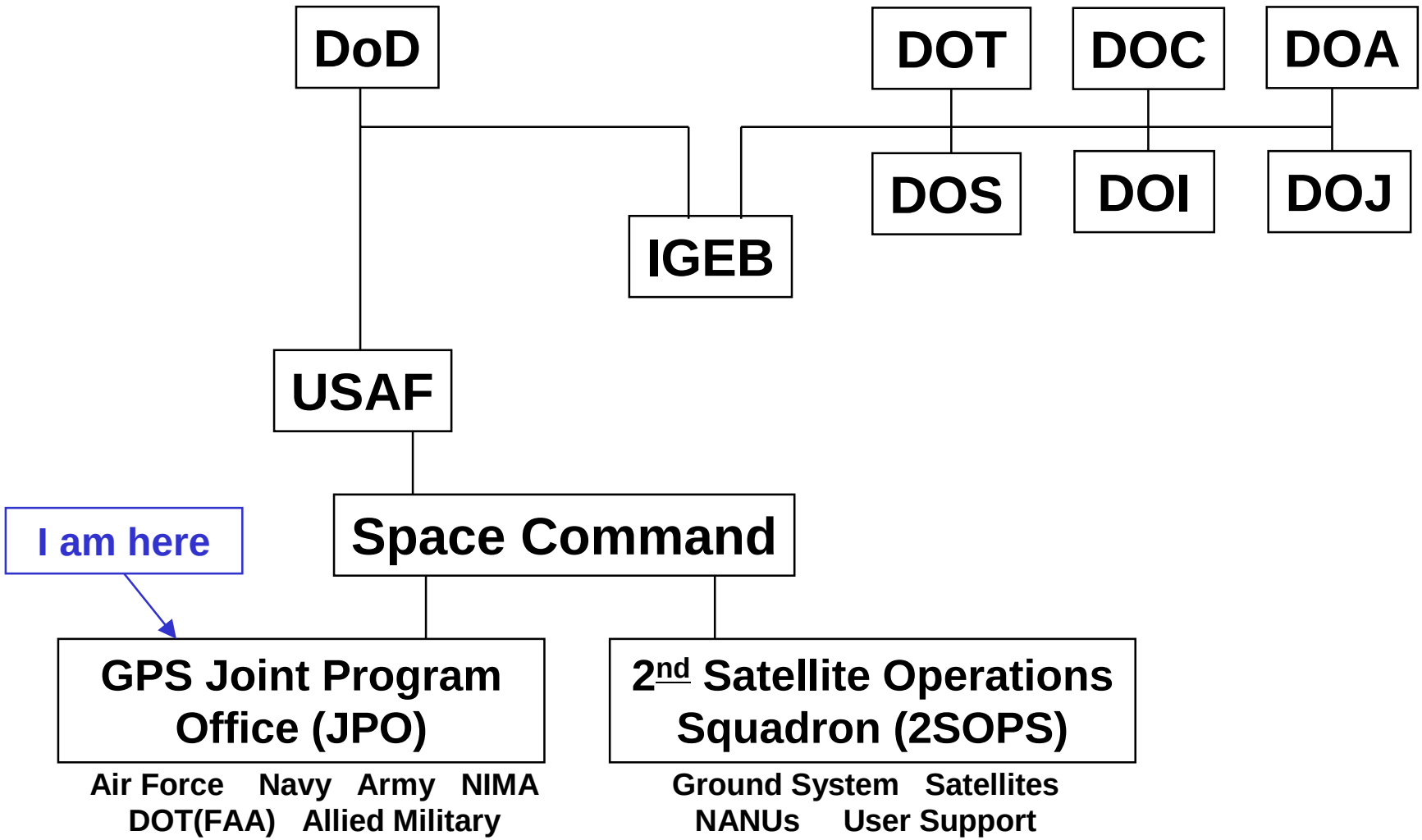
GPS is...

- **Originally a Military Warfighter Support System**
  - Global grid for coordinated position and time synchronization
    - Navigation, rendezvous, mine warfare, weapon delivery, etc.
  - Funded, managed, and operated by the DoD since 1973
    - Civil access to GPS granted in 1983 by President Reagan
- **Now a Critical Dual-Use National Asset**
  - More essential to military forces than ever imagined
    - Current example: precision guided munitions (smart bombs)
  - Becoming indispensable to civil/commercial users
    - Transportation, communication, disaster response, etc.
  - Still funded, managed, and operated by the DoD
    - Ground system, satellites, and receivers for military users
    - Ground system and satellites for civil/commercial users

GPS Program


DoD
DOT
DOC
DOA
DOS
DOI
DOJ
IGEB
USAF
I am here
Space Command
GPS Joint Program Office (JPO)
Air Force Navy Army NIMA
DOT(FAA) Allied Military
2nd Satellite Operations Squadron (2SOPS)
Ground System Satellites
NANUs User Support

GPS JPO Challenges

- **Maintain Constellation while Adding Capabilities**
  - On-orbit satellite constellation sustainment strategies
    - Multiple blocks of satellites (II, IIA, IIR now; IIR-M, IIF soon)
  - Ground system upgrades and modernization
    - Operational Control System (OCS), training for 2SOPS crews
  - Testing / validating new signals - design and operations
- **Capturing Future User Needs - Military and Civil**
  - Best way to understand military operational needs
  - Best way to understand civil “value added” needs
- **Procurement Strategies to Enable Future Growth**
  - Ability to forecast GPS user requirements through 2030
- **Reducing Total Ownership Costs**
  - Weigh costs and benefits to make the right system trade-offs

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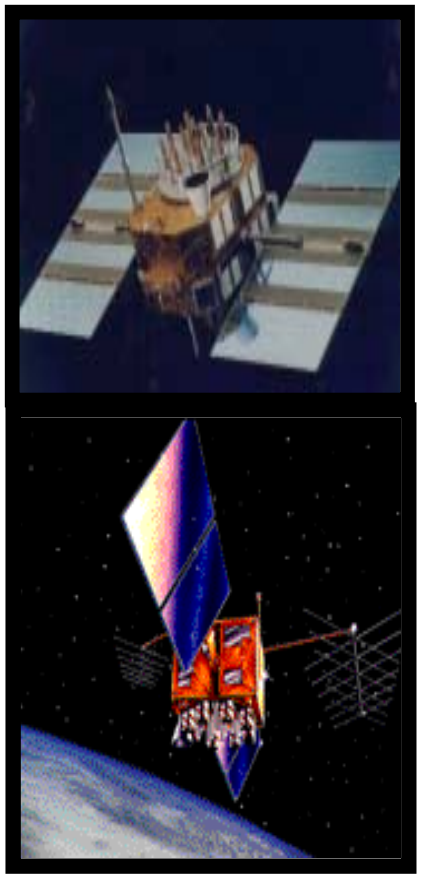
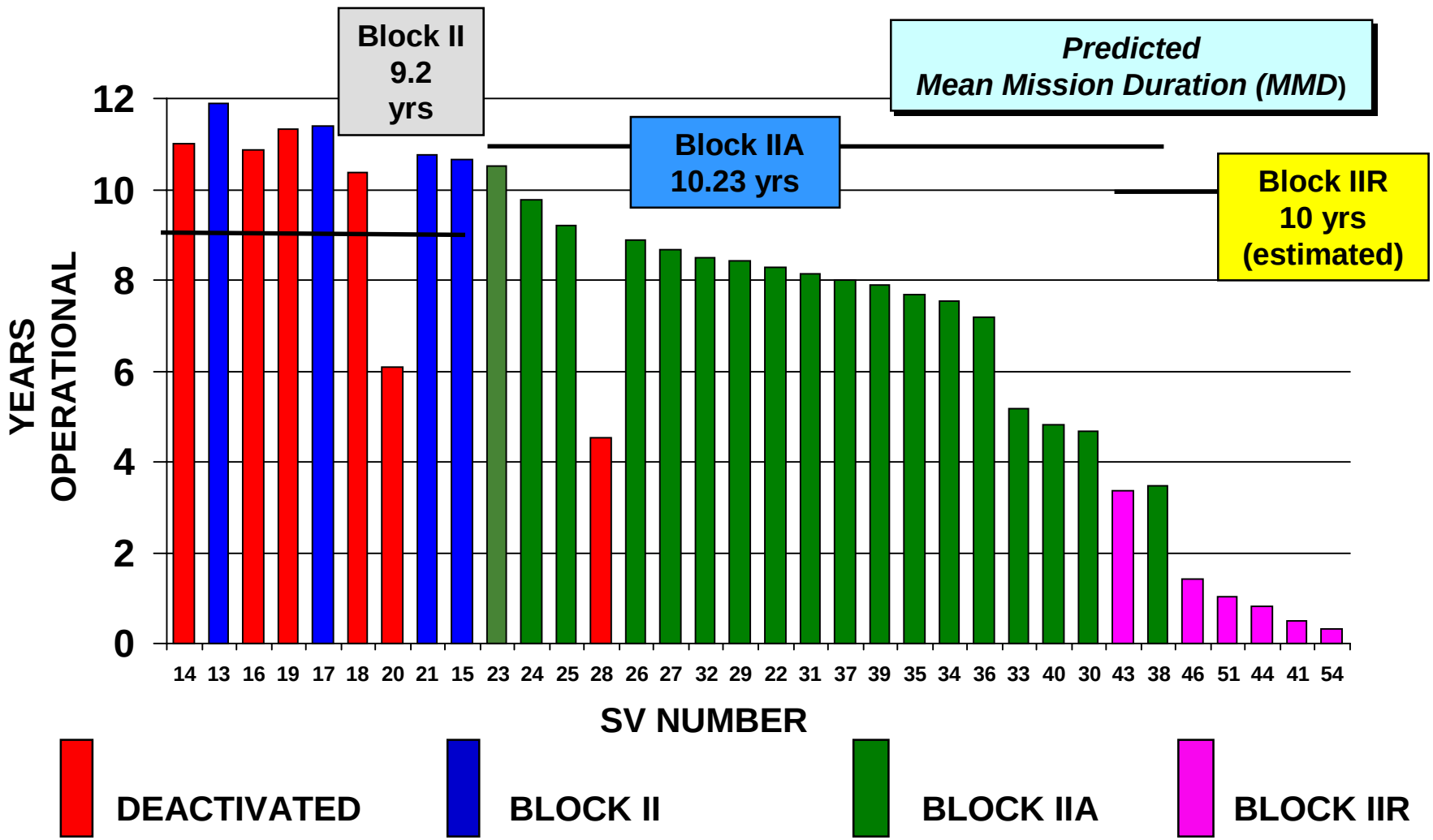
Constellation Status

28 Operating Satellites

- **22 Block II/IIA Satellites in Orbit**
  - Block IIA life expectancy reduced slightly (to 10.23 years)
- **6 Block IIR Satellites in Orbit**
  - Last launch 31 Jan 01
  - 14 of 21 Block IIR satellites available
  - Modernizing up to 12 Block IIR satellites
- **Continuous Assessment of Launch Need**
  - Next Launch: Mar 02
  - Tentative launch dates: Jun 02; Oct 02

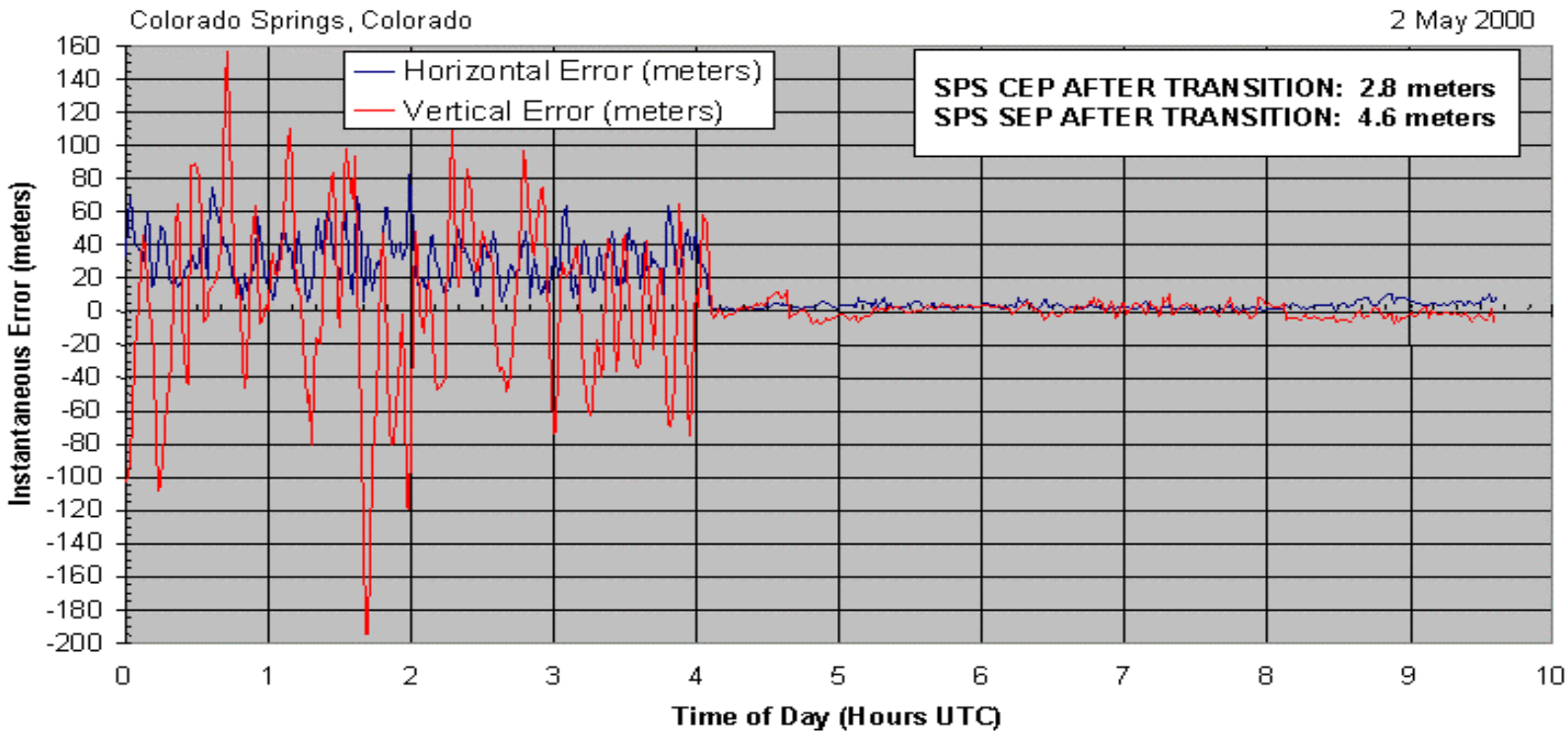


GPS Constellation Snapshot



SA Set to Zero on 2 May 2000

- **Selective Availability (SA) = Intentional Degradation**
  - Had been applied to civil signal to discourage hostile exploitation
  - President decided to discontinue SA to aid peaceful civil users
  - Civil user accuracy dramatically increased on 2 May 2000



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New Civil Signals

- **Some Consider as 2nd/3rd Steps of Modernization**
  - Many civil users consider setting SA = 0 as the 1st step
  - Not really true, but close enough for this presentation
- **Civil Users Currently Limited to One GPS Signal**
  - C/A-code at L1 frequency (1575.42 MHz)
    - Low power signal, not intended for precision navigation
    - C/A = "Coarse/Acquisition" (c.f. P-code; P = "Precise")
- **Adding a Second Civil Signal**
  - C/A-type code at L2 frequency (1227.60 MHz)
    - Low power signal, not intended for precision navigation
- **Adding a Third Civil Signal**
  - P-type codes at L5 frequency (1176.45 MHz)
    - Higher power signal, intended for precision navigation

New Civil Signal Roll-Out

- **Second Civil Signal (L2C) - Block IIR-M Satellites**
  - First launch in 2003, then every satellite thereafter
  - Provides a redundant signal for civil users
    - Improved continuity in case L1 signal reception is lost
    - Improved accuracy via dual-frequency ionosphere correction
    - Wide-lane for extremely-precise local area differential GPS
- **Third Civil Signal (L5) - Block IIF Satellites**
  - First launch in 2005, then subsequent satellites thereafter
  - Provides redundant dual-frequency capability for civil users
    - Improved continuity in case L1 or L2 signal reception is lost
    - Improved accuracy via triple-frequency ionosphere correction
    - Tri-lane for ultra-precise local area differential GPS
  - Provides an interference-resistant signal for civil users

Block IIR Modernization

Pre-Modernization

- **Heritage Signals**
  - L1 C/A
  - L1, L2 P(Y)
- **Design Life**
  - 10 Years

Post Modernization

- **Modernized Signals**
  - Higher Power
  - L1 C/A, L2C*
  - L1, L2 P(Y)
  - L1, L2 M-Code
- **Design Life**
  - 10 Years

*** L2 Second Civil signal design supports varying code length and data structure**

Block IIF Modernization

Pre-Modernization

- **Heritage Signals**
  - L1, L2 C/A
  - L1, L2 P(Y)
- **Design Life**
  - 15 Years

Post Modernization

- **Modernized Signals**
  - Similar Power
  - L1 C/A, L2C*
  - L1, L2 P(Y)
  - L1, L2 M-Code
  - L5 Third Civil**
- **Design Life**
  - 12 Years
  - 10 Year MMD

*** L2 Second Civil signal design supports varying code length and data structure**
**** L5 Third Civil signal design provides better jamming resistance than P(Y)-code**

Control Segment Modernization

Pre-Modernization

- **Upgrade Schedule**
  - Version 3/4
    - 1402 KSLOC
    - Delivery Sep 01
  - Version 5
    - 269 KSLOC
    - Single Delivery Sep 03 / Ops Jan 05
    - High Risk
  - Version 6
    - Size 34 KSLOC
    - Delivery Sep 05 / Ops Mar 07

Post-Modernization

- **Upgrade Schedule**
  - Version 3/4
    - 1402 KSLOC
    - Delivery Sep 01
  - Mod Test Legacy Upgrade
  - Version 5
    - 300 KSLOC
    - Incremental Deliveries begin Jun 02; Ops Jan 05
      - Moderate Risk
  - Version 6
    - Size 184 KSLOC
    - Delivery Sep 05 / Ops Mar 07

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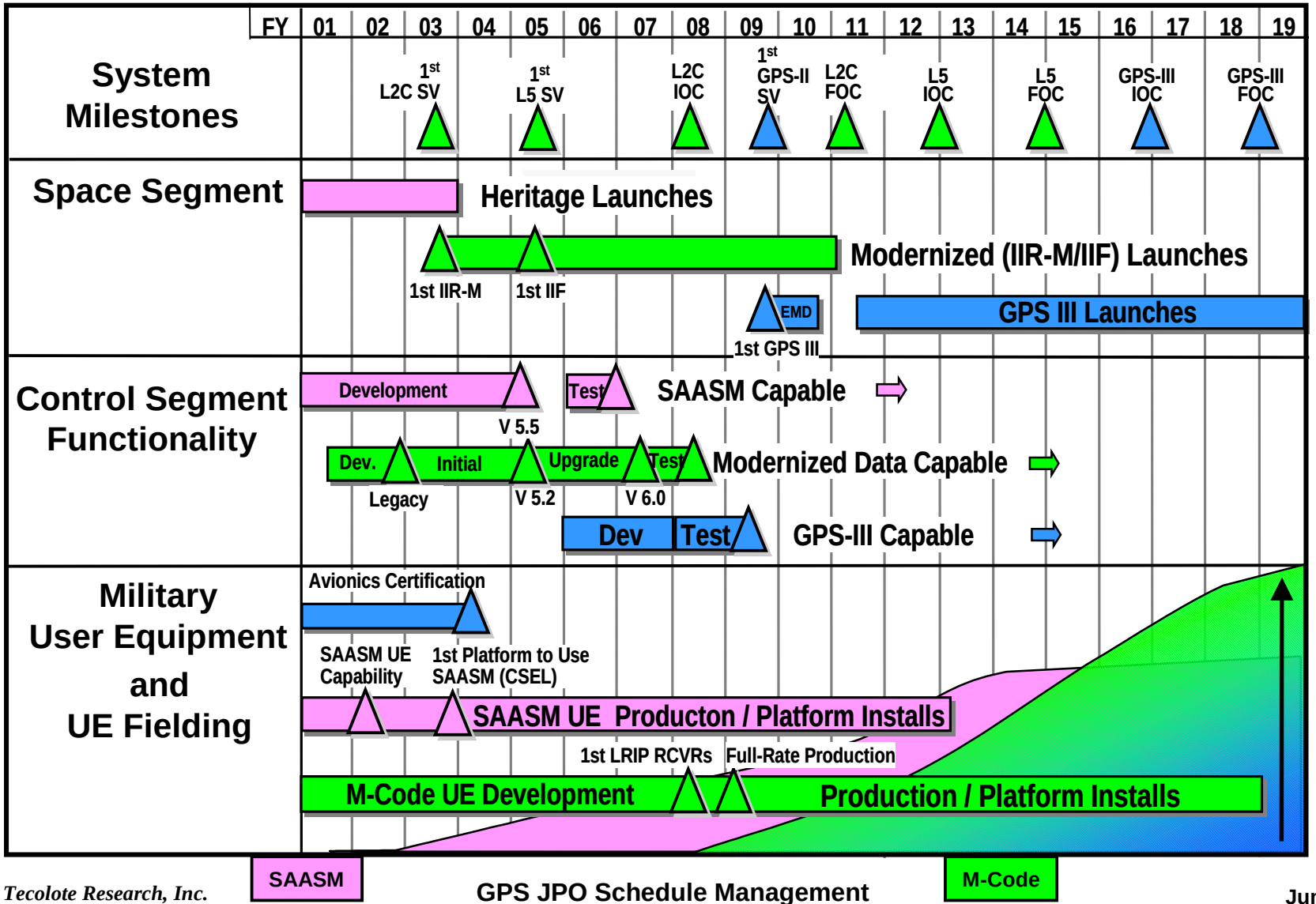
GPS Enterprise Perspective



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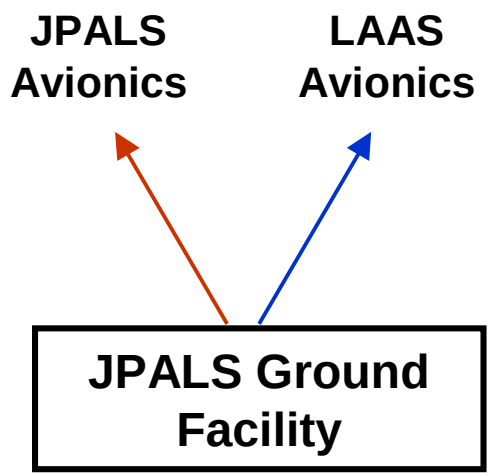
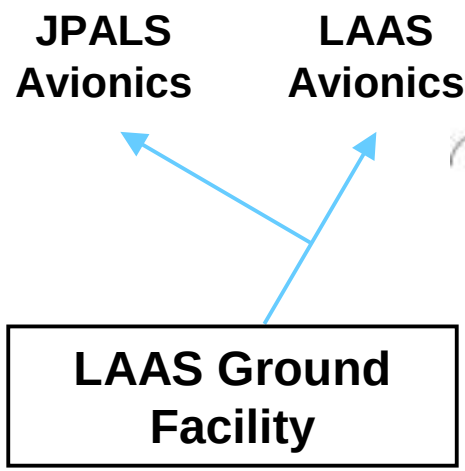
Ground Augmentation

- **By itself, GPS has Good Accuracy and Integrity**
  - Good enough for most navigation applications
- **Ground Augmentation Gives Major Improvements**
  - For Ultra High Accuracy
    - ~1 m with Local Area Differential GPS (LADGPS)
    - ~1 cm with Real-Time Kinematic (RTK)
  - For Ultra High Integrity
    - ≥1-1x10^{-9}/operation or even better is achievable
- **Precision Landing Needs High Accuracy/Integrity**
  - Prime example of GPS ground augmentation system usage
    - Civil: Local Area Augmentation System (LAAS)
    - Military: Joint Precision Approach and Landing System (JPALS)

JPALS CAT-I/II Architecture

- **JPALS: Military LADGPS System**
  - LAAS look-a-like (based on RTCA standards)
  - JPALS uses both military and civil GPS signals
  - Operate during electronic attack (collateral jamming)
  - Fixed base, tactical, and special mission applications
  - Civil (LAAS) interoperable...





JPALS Anti-Jam Testing

- 276 approaches, approx half in jamming
- Number and power of jammers varied
- Beam-on-SV & null-steering technology
- Operational potential successfully demonstrated

JPALS Civil Interoperability Testing

- FedEx 727-200, LAAS-type avionics
- 16 CAT-I and 6 Autolands
- C/A-code operation
- CAT-II level of performance

Shipboard Relative GPS Testing

- **10 Fully Auto-Coupled Landings (Mode I's) to deck**
- **Landing Dispersion (1-sigma)**
  - 15 ft (along the deck)
  - 11 cm average navigation accuracy at touchdown

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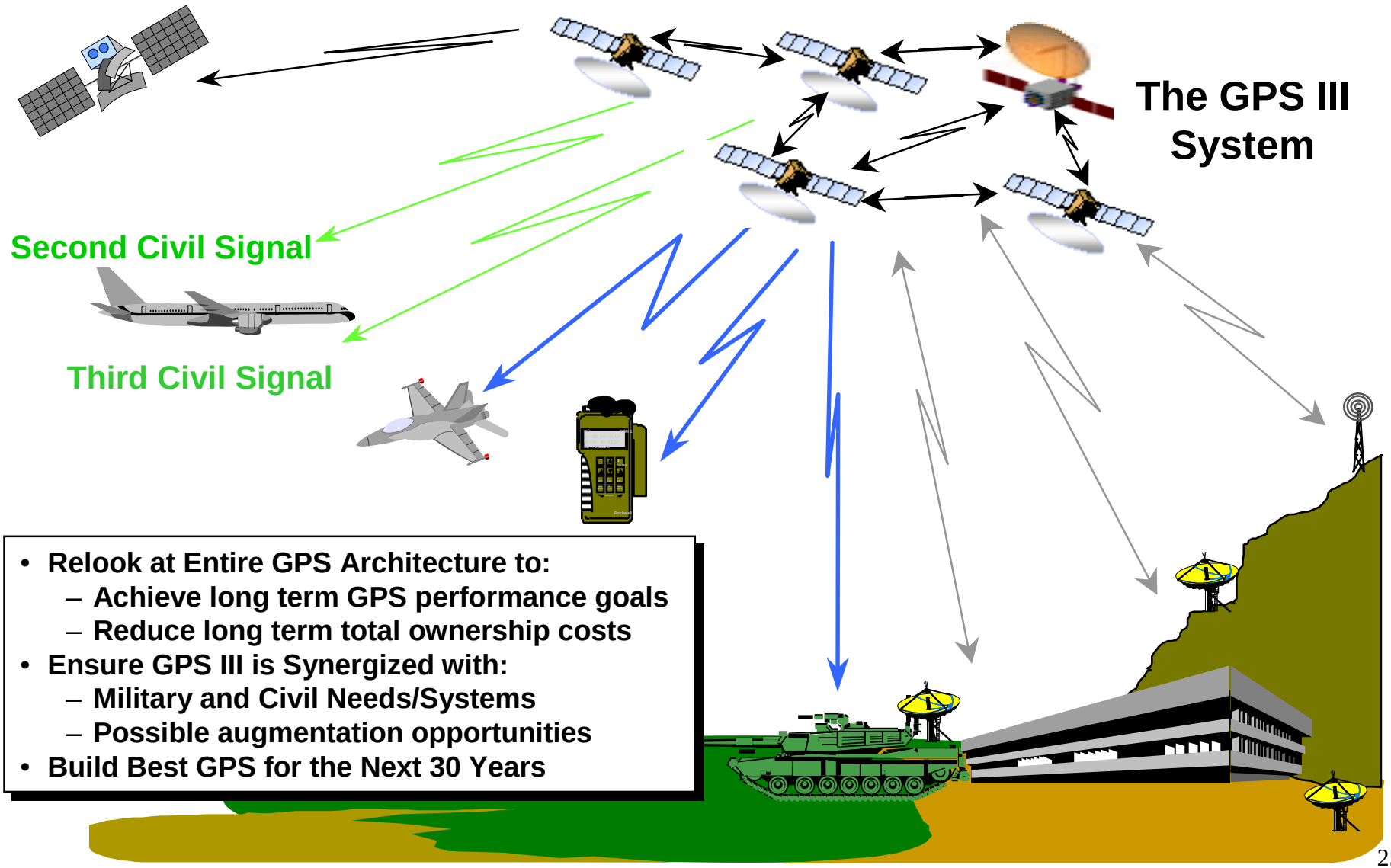
GPS III System Description



- Relook at Entire GPS Architecture to:
  - Achieve long term GPS performance goals
  - Reduce long term total ownership costs
- Ensure GPS III is Synergized with:
  - Military and Civil Needs/Systems
  - Possible augmentation opportunities
- Build Best GPS for the Next 30 Years

GPS III Integrated Approach

- **GPS Originally Designed without benefit of an Established User Base**
- **Civil Users Previously Solicited for Suggested Changes to Existing System to Meet their Needs**
- **GPS III has Novel Approach for Integrating Needs of the DoD, DOT, FAA…**
  - Just completed System Architecture and Requirements Definition phase gathered and identified future requirements
  - Interagency Forum for Operation Requirements created to identify and assemble new requirements for GPS
  - Civil and military requirements to be approved in totality by joint committee
  - Coast Guard Navigation Center soliciting requirements via website

GPS III Increased Capability

- **Assured Delivery of GPS Signals**
- **Higher Power Military & Civil Signals**
- **Higher Accuracy Service for All Users**
- **Increased Integrity Inherent in GPS**

GPS III Assured Delivery

- **Dual-Use GPS is more than just Adding Civil Signals**
  - Assuring availability and continuity of signals
- **Realization that GPS is considered a Critical Part of Worldwide Infrastructure**
- **Availability/Continuity Key Factors in GPS III Design**
  - Crosslink architecture
  - Number of orbital planes
  - Number of satellites
  - Sparing strategy
  - Replacement strategy
  - Control segment

GPS III Higher-Power Signals

- **Military has Needed Better A-J for Long Time**
  - GPS likely candidate for electronic attack during wartime
  - Transmitting signals with higher power is part of solution
    - Another one of the key aspects of assured delivery
  - Military-only M-code allows transmitting with higher power
    - Backwards compatibility a mandatory requirement
- **Civil Users Starting to Recognize Need for A-J**
  - Volpe Vulnerability Assessment
    - Accidental interference
    - Intentional jamming and/or spoofing
  - Third civil signal at L5 is step in right direction for A-J
  - Other GPS III opportunities for regulated "public safety" users

GPS III Increased Accuracy

- Augmented and standalone missions identified that require more accuracy than modernized GPS
- Signal-in-space improvements must keep pace with those in users equipment
- Advanced technology clocks and inter-satellite ranging - more accurate signal-in-space
- More timely updates and improved models

GPS III Increased Integrity

- **Aviation applications one of key drivers**
- **Other safety-of-life uses also considered**
- **Important military need for integrity is to reduce of collateral damage**
- **GPS III architectural changes**
  - Improved monitoring and reporting
  - Planned interfaces between GPS and augmentations
  - Potential for meeting broad array of civil and military needs via GPS alone

Sufficient Means of Navigation

- **Sufficient to be used anywhere, anytime**
  - Without precluding use of other systems or augmentations
  - Without requiring use of other systems or augmentations
    - Except for most demanding applications (JPALS/LAAS)
  - With assured delivery
    - Availability and continuity (and higher power)
  - With high accuracy
  - With high integrity

End State for Aviation

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Summary

- **GPS Modernization activities well underway**
- **GPS Modernization offers superb opportunity to satisfy both military requirements and civil needs**
  - GPS III exploring complementary DoD/civil augmentation opportunities
- **Working through challenges**
- **GPS III Architecture – Working hard toward a robust, supportable, flexible, national capability for the next 30 years**

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Your Involvement

- **Interested in receiving your inputs**
- **GPS III Draft System Specification available**
  - Review and submit comments
- **Opportunities to provide additional input through industry, professional and international associations**