



The Impacts of GPS Modernization on DAG-TM

*DAG-TM Workshop
CNS Breakout Session*

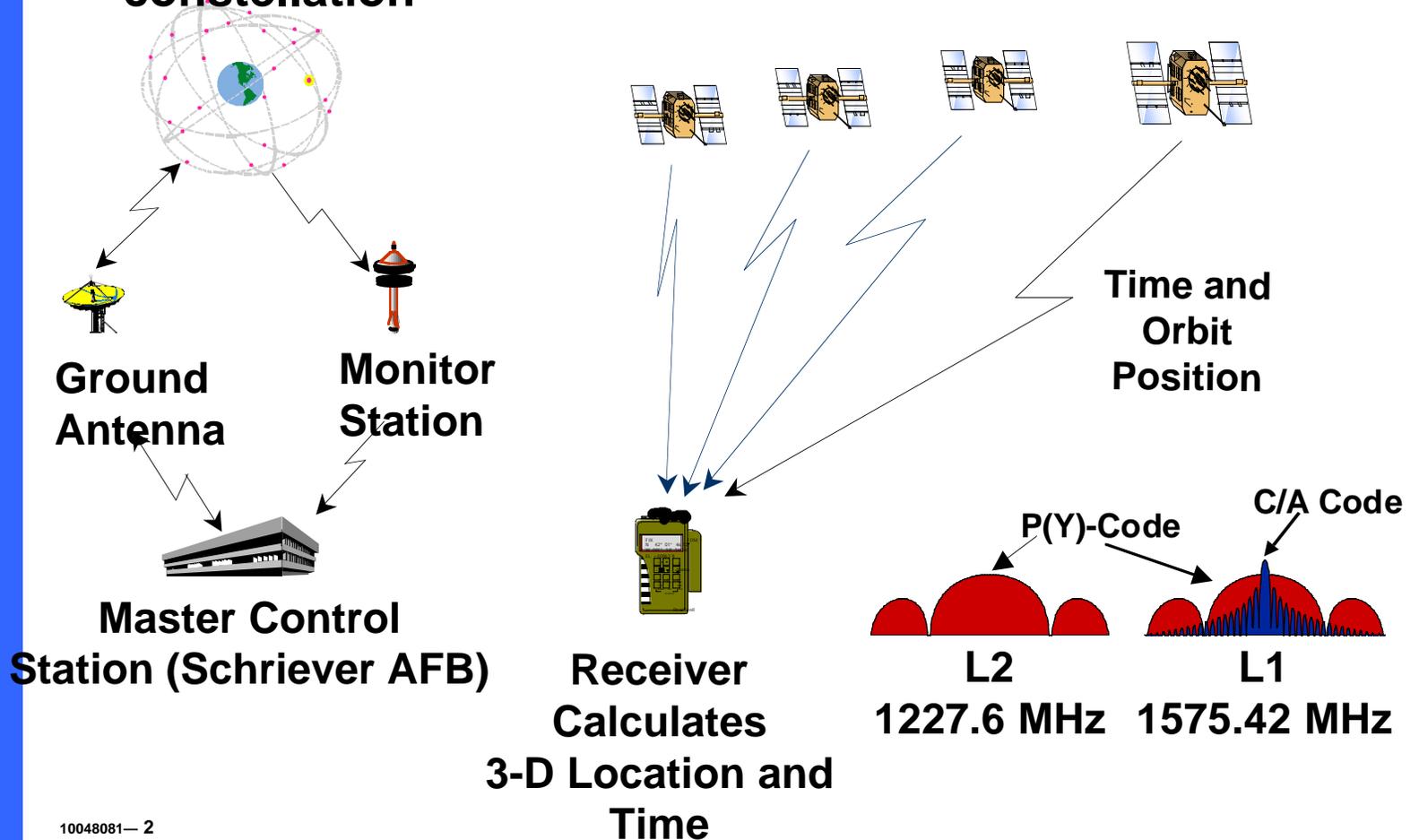
May 24, 2000

Hank Sielski



Global Positioning System (GPS) Overview

24-satellite (nominal) constellation



Basic GPS SPS (Civil) System Performance

- **Accuracy:**
 - **Before 1 May 2000: 25-100m 3D 95%**
 - **C/A Code on L1**
 - **Selective Availability**
 - **Today: 6-11m 3D 95%**
 - **C/A Code on L1**
 - **SA Set to zero**

Current Basic GPS System Limitations

- **Integrity**
 - Notification Time: >15 Minutes
 - Not Sufficient for Civil Aviation

}	WAAS (CAT-I) - 6 sec
	LAAS (CAT-II/III) - 2 sec
- **Availability**
 - 24 Satellites - 70%
 - 21 Satellites - 98%
 - Not Sufficient for Primary Means Navigation

}	WAAS (CAT I) - 99.9%
	LAAS (CAT II/III) - 99.999%
- **Accuracy**
 - Enroute Through Non-precision - OK
 - Not Sufficient for Precision Approaches

}	WAAS (CAT I) - 7.6 m
	LAAS (CAT II/III) - 1 m
- **Not Sufficient for Safety of Flight for All Operations**
 - Currently only certified for Oceanic routes

GPS Augmentations

- **Needed for integrity, availability, and (and to a lesser extent) accuracy improvements to current basic system**
- **FAA sponsored augmentations**
 - **Wide Area Augmentation System (WAAS)**
 - **Technical issues delay deployment**
 - **Local Area Augmentation System (LAAS)**
 - **Program really just starting**
- **GPS III Modernization will consider augmentations as part of total service improvements: system of systems approach**

WAAS Problem Areas

- **Two Problems Have Been Identified during Phase I deployment:**
 - **Stability**
 - **Integrity**
- **Problems Preclude FAA Commissioning of Any Level of Service in FY00**
 - **Earliest IOC (Phase I Deployment) is CY2002**
- **Other potential problems could affect schedule for FOC and final disposition of other Nav aids**
 - **number of Geosat transponders needed for availability/integrity**



Why Modernize GPS?

- **Better support the warfighter in the evolving threat environment**
 - More signal power = more anti-jam
 - More secure new military code structure
 - More User Equipment anti-jam capability = more protection
 - Better able to deny an enemy use of GPS

**Joint Requirements Oversight Council (JROC)
validated requirements in Jun 99**

- **Better support to civil GPS customers**
 - New civil signals for improved accuracy, integrity and continuity of service = robustness
 - Compatibility with and further support for civil aviation systems

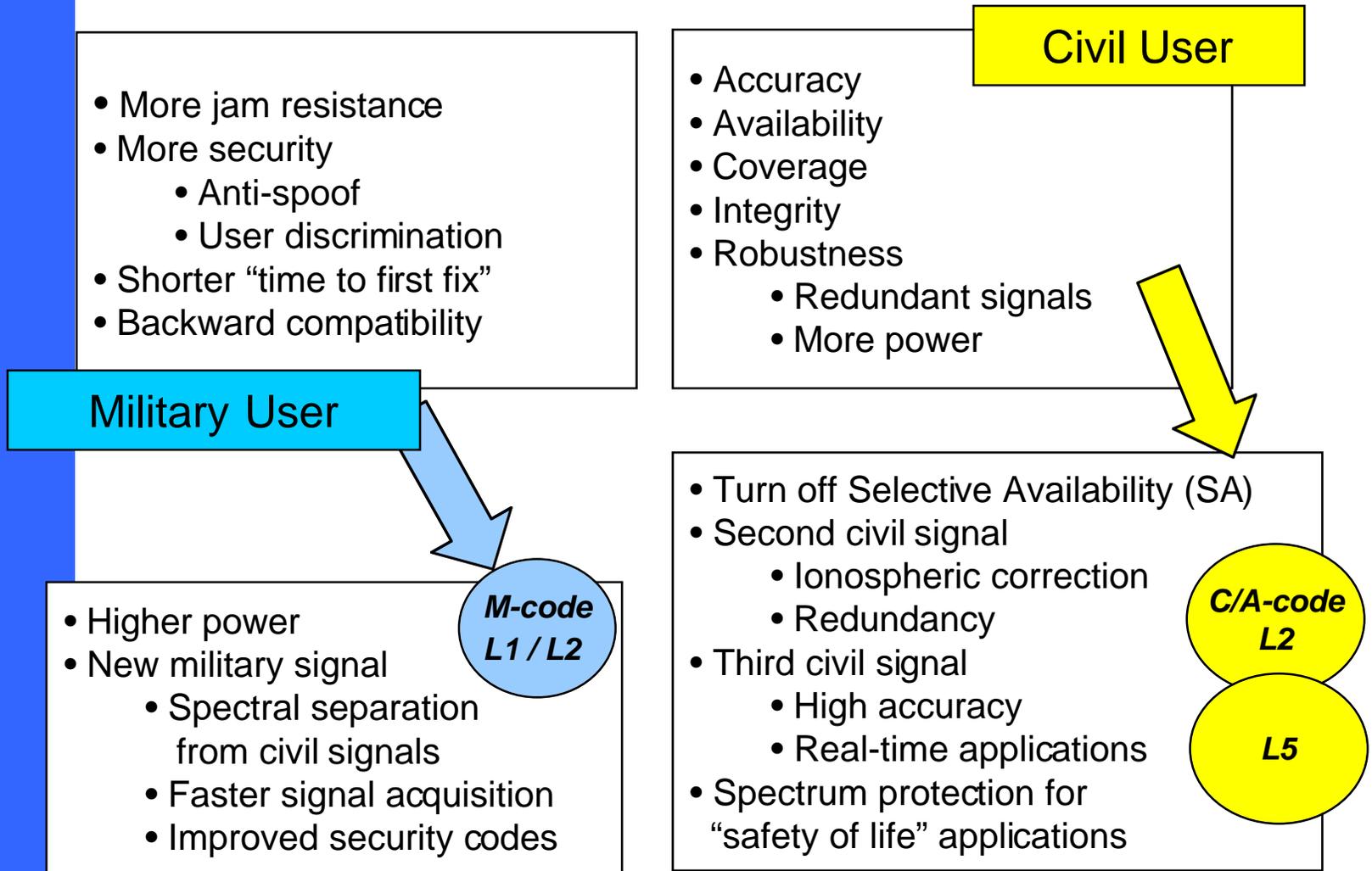
**Presidential Decision Directive - Mar 96
Vice Presidential Announcements - Mar 98 and Jan 99**

GPS Modernization History

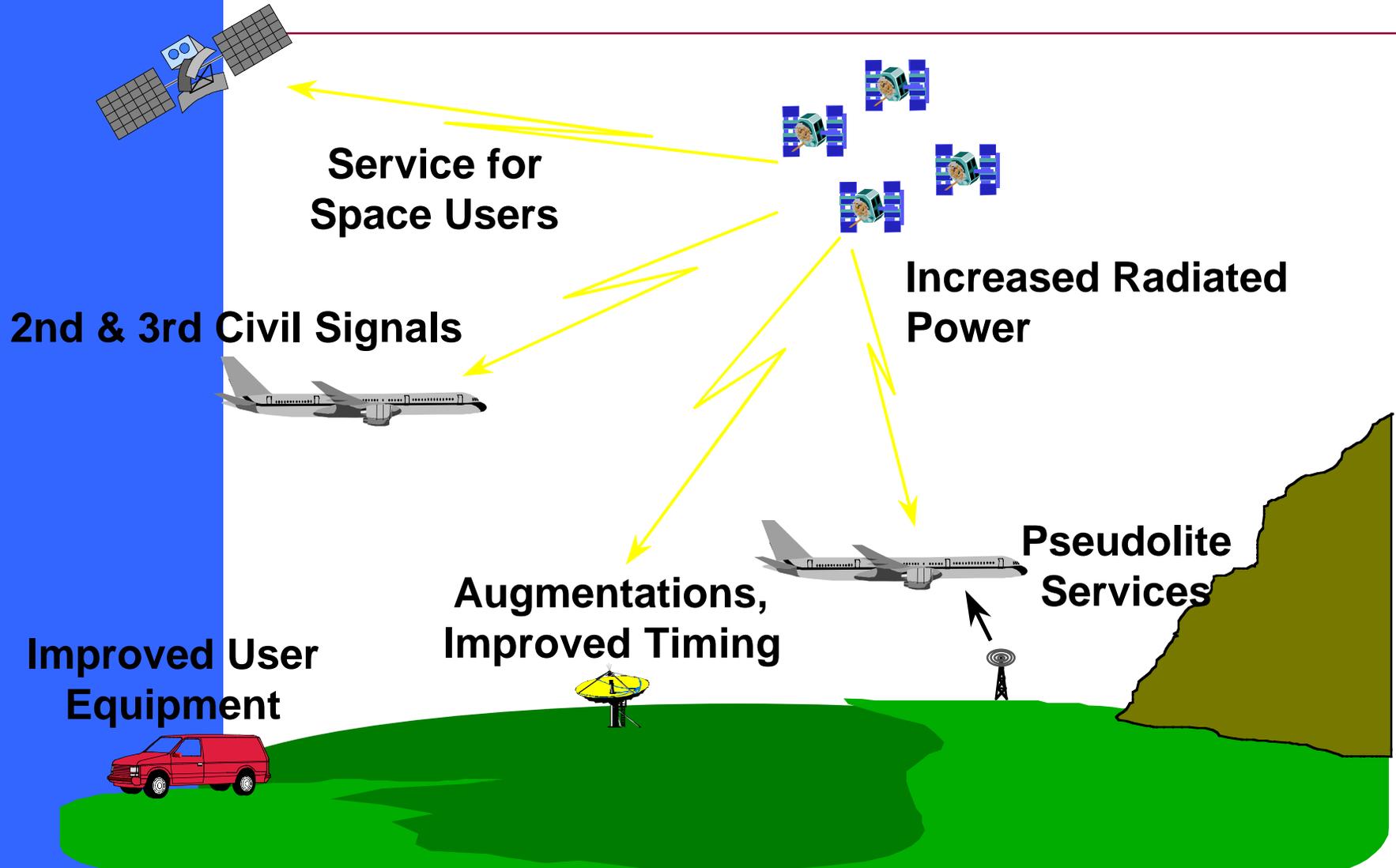
- **Grew out of NAVWAR Studies in 1996**
- **Prime focus on military signal needs during 1997-1999 studies**
 - **Developed M-Code architecture (still being finalized)**
 - **Drafted new civil signal designs and integrity approaches**
 - **Modernization envisioned as ECP to IIF**
- **December 1999 JPO reorients to current strategy**
 - **However, congressional new start authority required**

**JPO STILL AWAITING CONGRESSIONAL NEW
START AUTHORITY TO PROCEED
IIR, IIF features solid, but all schedules are “notional”**

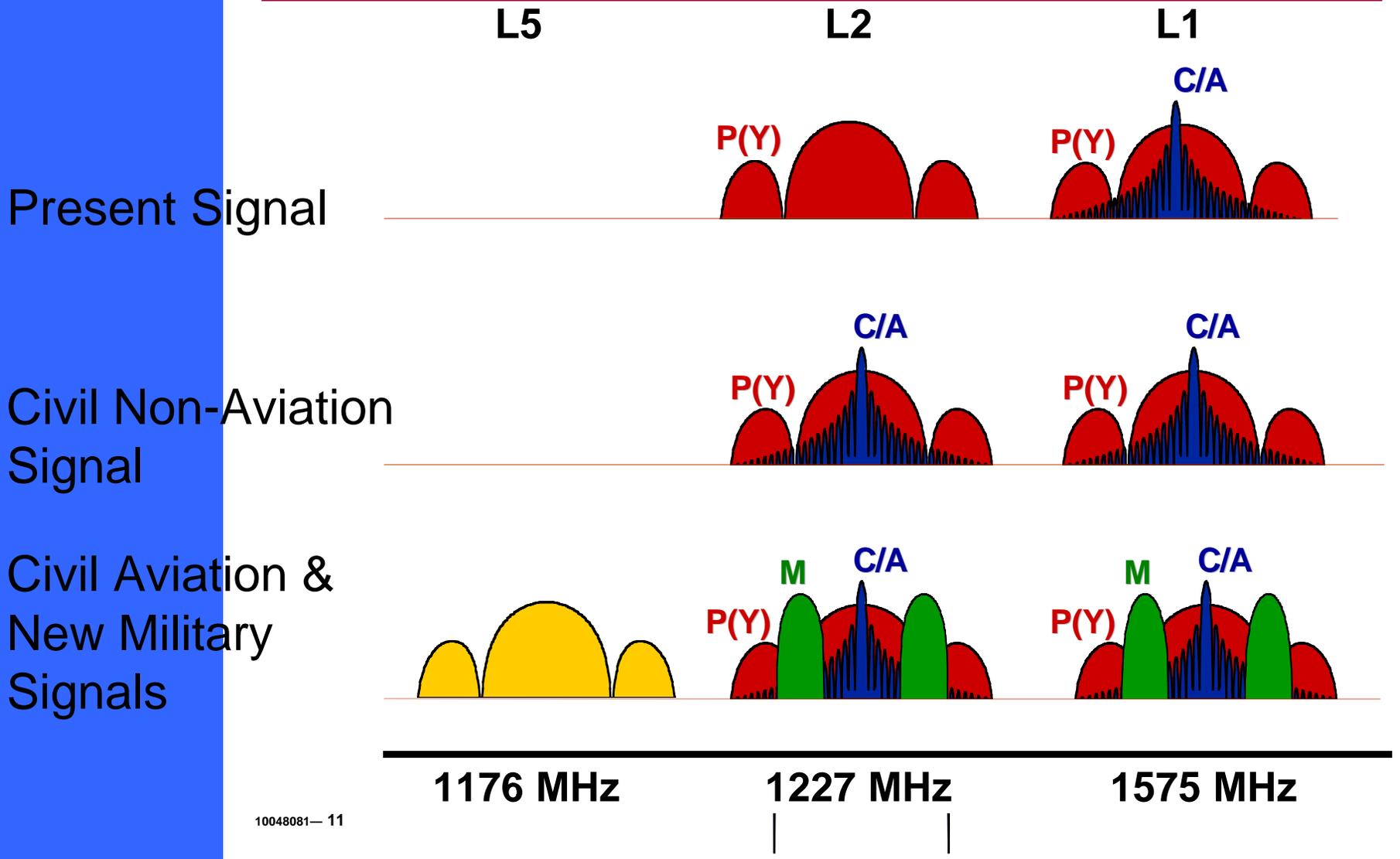
What GPS Users Want from Modernized System



GPS Modernization: System of Systems



Evolution of Modernized GPS Signals





L5 Signal Specification Schedule

- **Signal Design essentially complete**
 - Draft 7 of spec updated with comments as of 6 May
 - Some specification details affected by SV design are replaced with comments
 - Phase Noise specification
 - Correlation Loss specification
 - Detailed Received Power specification
- **May 16 - Draft signal specification mailed for ballot vote**
- **June 16 - SC159 Plenary vote**
- **Late summer - Next RTCA Program Management Committee (PMC) meeting (PMC approval necessary for RTCA publication)**
- **Dec. - Interagency GPS Executive Board (IGEB) approved specification to JPO for definitized contract**

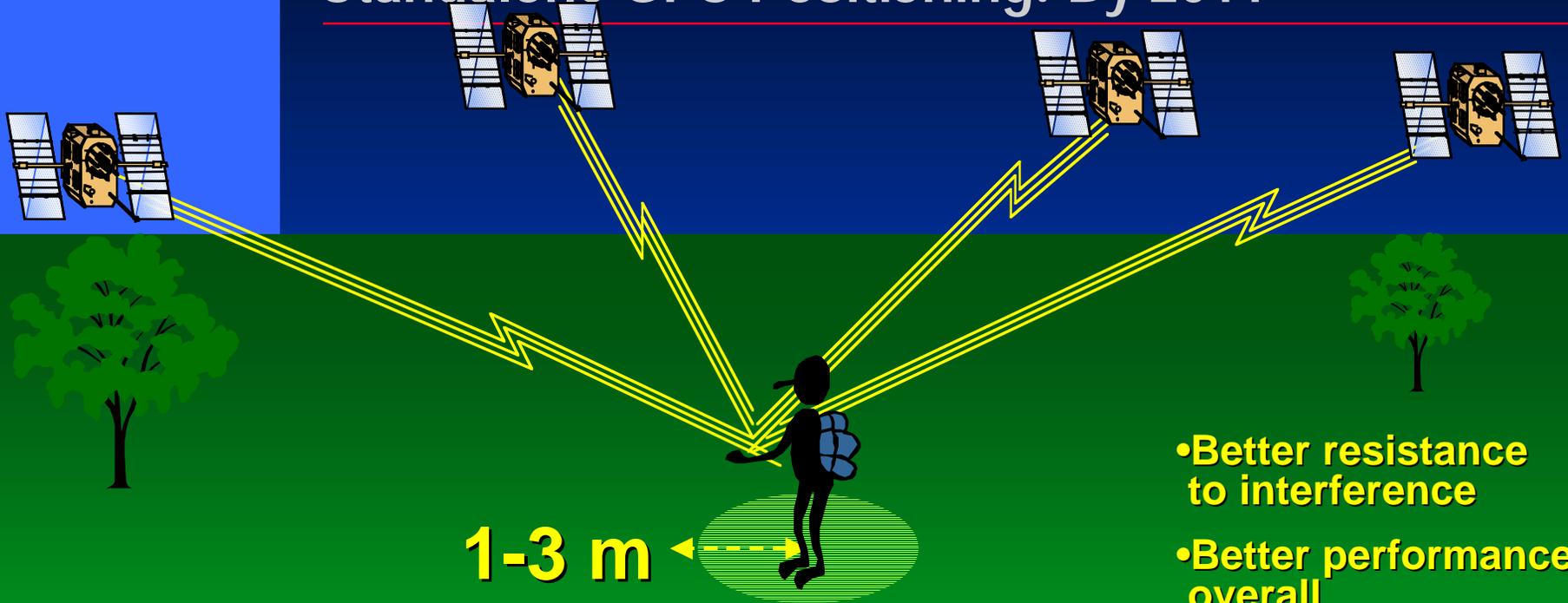


GPS Modernization Program: Summary

- **Last 12 Block IIRs - add second civil signal (C/A on L2) and new military signal (M-code) - more signal power**
- **First 6 Block IIFs (“IIF Mod Lite”) - all of above capabilities plus new third civil signal in protected band (L5).**
- **Next [nominally] 6 Block IIFs - procured as necessary to sustain the constellation.**
- **GPS III (Full Modernization) - meets future requirements through 2030 - more M-code signal power - address augmentations**
- **First modernized launch (Block IIR) - FY03; first Block IIF “Lite” launch - FY05**
- **M-code (earth coverage) IOC (18 satellites) FY08; Full Performance IOC FY16; FOC FY19 (24 GPS IIIs Flying)**
- **New Civil signal IOC FY08 for 2nd; FY11-12 for 3rd (dependent on IIF modernization expansion)**
- **OCS - evolutionary incremental development**
- **UE - open systems architecture for upgrades; more AJ**



Standalone GPS Positioning: By 2011



- Better resistance to interference
- Better performance overall

- C/A Code on L1
- C/A Code on L2
- New Code on L5

DAG-TM Benefits of GPS Modernization: By 2011



- **More reliable and accurate positioning worldwide!**
- **Reduced delays**
- **More fuel-efficient routes**
- **Increased system capacity**
- **Increased safety for negotiated or free-flight determined routes**

With or Without WAAS!

GPS Modernization and Current Augmentations

GPS-III

*could provide a fundamentally sound systems approach
to integrity and accuracy
without relying on separate differential system*

- **Reduce or eliminate need for any expansion of Wide Area Augmentation system for enroute support**
 - Reduce need for additional WAAS Geosats to provide necessary availability, integrity
 - Reduce urgency of Civil community to provide a separate integrity channel on L5
- **Compatible with and improves performance of LAAS for Approach, Terminal and Surface Management applications**



Backup Slides

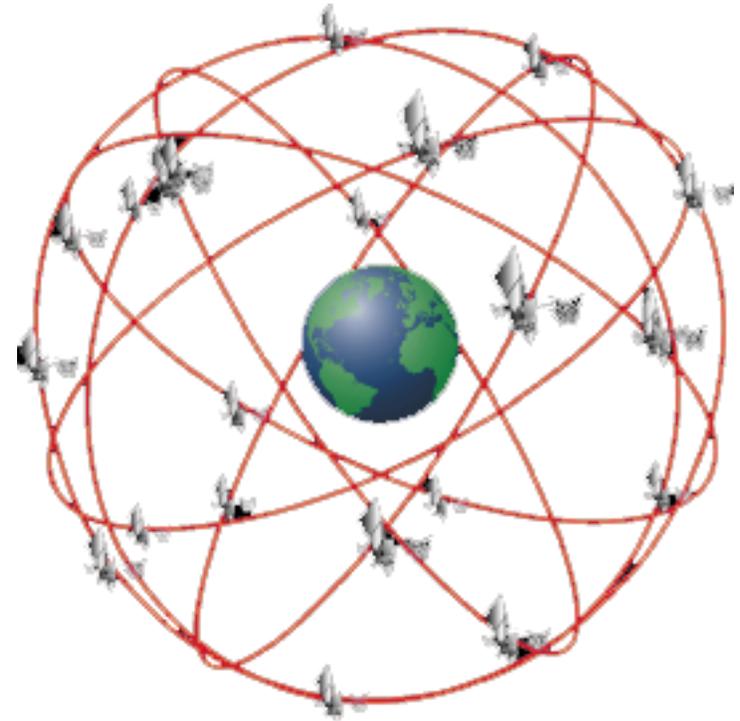
GPS History

- **Active program for over 25 years**
 - **Created by DoD from separate technology programs in 1973**
 - **Developmental satellites began launch in 1978**
- **Operational satellites began launch in 1989**
 - **Initial Operational Capability - 1993**
 - **Full Operational Capability –1995**
- **Open civil navigation service**
 - **Signal specification available to industry and all users, both US and International**

Basic GPS System

- **Space Segment**
 - 24 Satellites
 - 6 Orbital Planes
 - 4 Satellites per Plane
 - Orbit at Approximately 11,000 Nautical Miles Above the Earth
 - Orbits Once Every 12 Hours

- **Control Segment - OCS**
 - Master Control Station, Colorado Springs
 - 5 Monitor Stations at Worldwide Locations

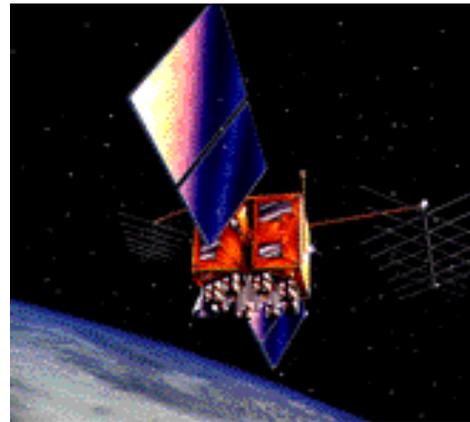


GPS Satellites



Block II/IIA

- All have been launched
- Rockwell (now Boeing)
- First launch Feb 1989
- 25 on orbit
- MMD 6.0/8.6/10.6 yrs



Block IIR

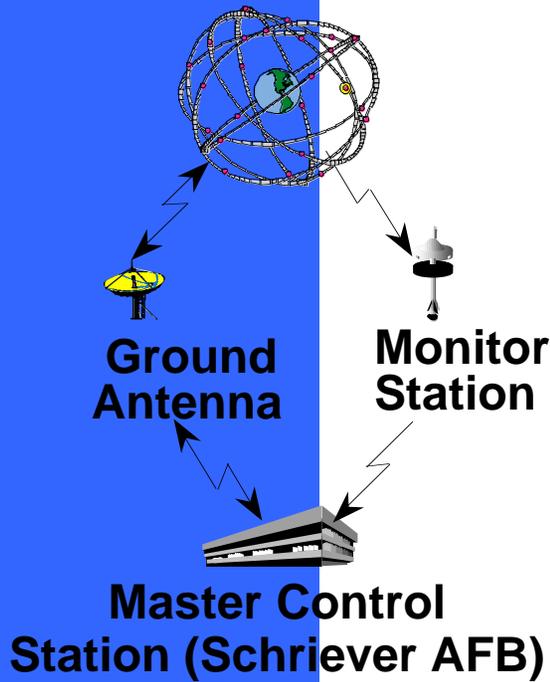
- In production
- Lockheed/Martin
- All 21 procured
- 2 on orbit
- 1 Destroyed on launch
- MMD 7.8 yrs



Block IIF

- In development
- Boeing(Rockwell)
- 6 already procured
- Options for 24 more without modernization
- MMD 12.7 yrs

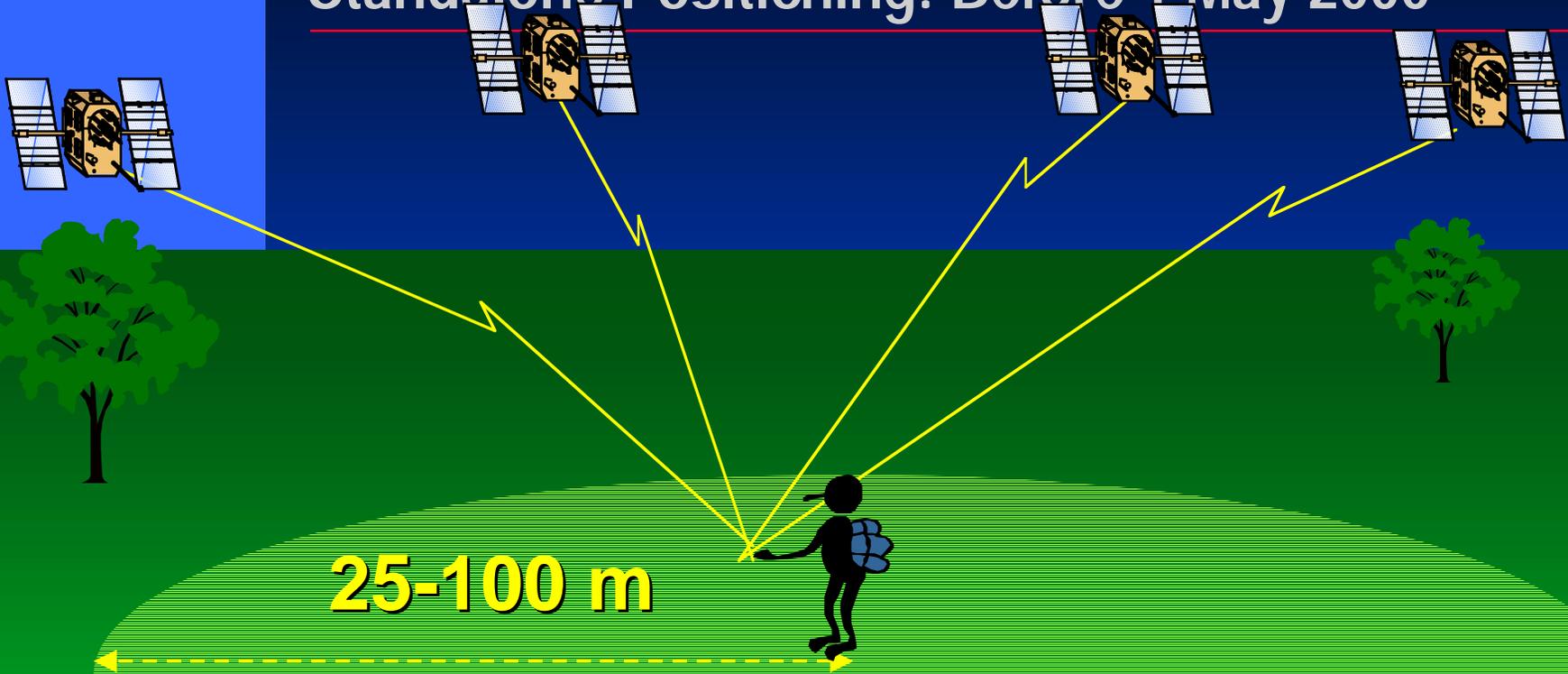
GPS Operational Control System (OCS)



- *Master Control Station (MCS):* **Satellite control, System operations**
- *Alternate Master Control Station:* **Training, Back-up**
- ◊ *Monitor Station (MS):* **L-band; Collect range data, Monitor navigation signal**
- ◊ *Ground Antenna (GA):* **S-band; Transmit data/commands, Collect telemetry**



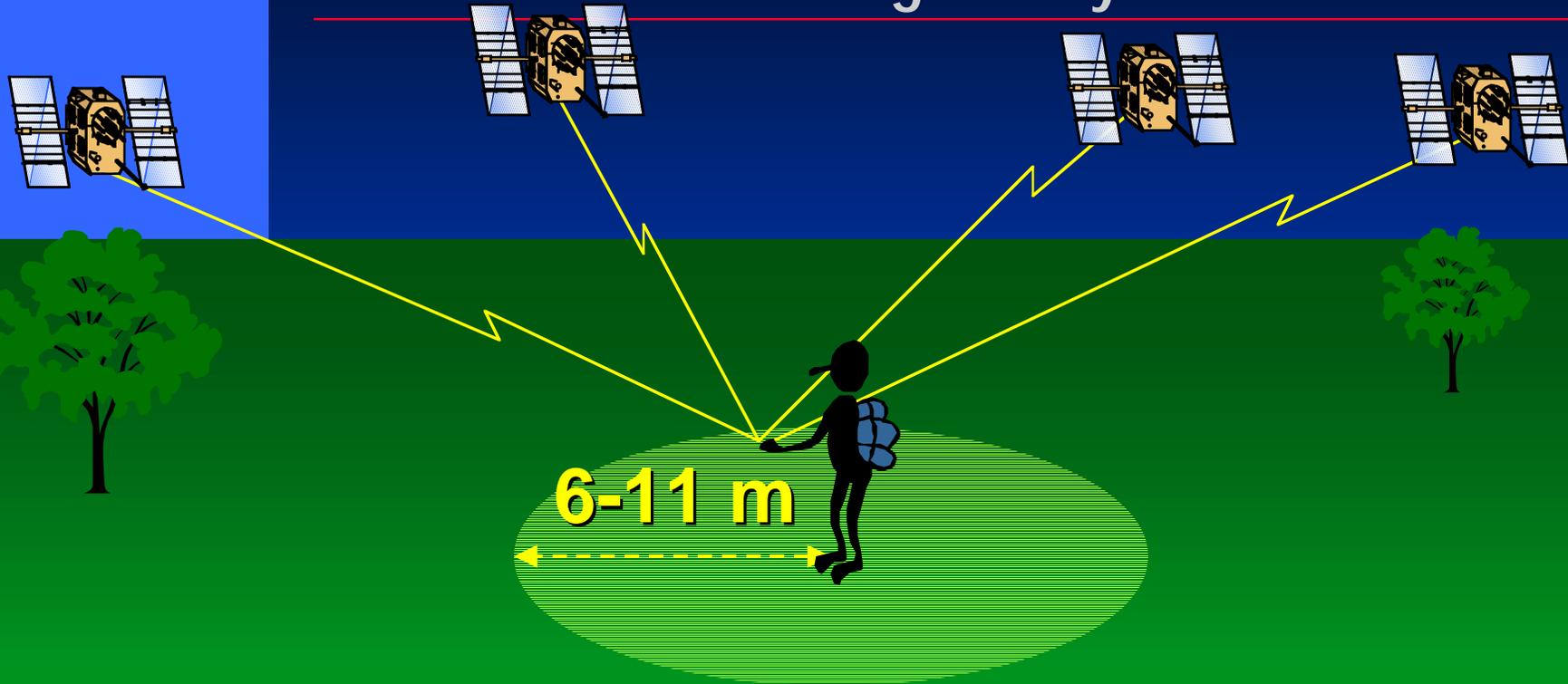
Standalone Positioning: Before 1 May 2000



- C/A Code on L1
- Selective Availability



Standalone Positioning: Today



- C/A Code on L1
- No Selective Availability



WAAS Stability Issue

- **Commenced 60-day Stability Test on Dec 13, 1999**
 - **Accuracy Required: 7.6 Meters**
 - **Accuracy Demonstrated: 2-3 Meters**
- **Test Halted After 30 Days Due To 100 Minute Signal Loss**
 - **Problems with Backup Geostationary Uplink Station (GUS) Transition Function**
 - **Software Problem in C&V Processor**
 - **Excessive Alarms**
- **Raytheon Working Corrections**
 - **Fixes for 4 of 7 Problems Have Been Identified**
 - **Fixes for Remaining 3 Problems Will Be Tested April/May 2000**

WAAS System Integrity

- **Problem Identified Meeting This Requirement**
 - **Analysis Indicates Integrity Monitors Do Not Work Correctly**
 - **HMI Event in Dec 99 - Monitor Did Not Detect**
- **Meeting FAA Safety Integrity Requirement is Most Significant Schedule Driver**
 - **No Greater Than One in 10 Million Chance of Failure for a Given Approach (Hazardously Misleading Information - HMI)**
- **WAAS Phase 1 IOC Projected not before CY2002**



GPS Modernization Program: IIR Modernization

Modify Block IIR Satellites (up to 12)

- **Second civil signal - C/A code on L2**
- **New military signal - earth coverage M code on L1 and L2**
- **Continue current military signal service - P(Y) code on L1 and L2**
- **More power for all signal services**
- **First launch in FY03 (tentatively)**

***Second civil signal and M-code
military capability
on-orbit as soon as possible***



GPS Modernization Program: IIF Modernization

Modify Block IIF Satellites (Mod Lite - 6 already under development)

- Second civil signal - C/A code on L2
- Third civil signal - new civil code on L5
- New military signal - earth coverage M code on L1 and L2
- Continue current military signal service - P(Y) code on L1 and L2
- More power for all signal services
- First Launch in FY05 (tentatively)

Options for additional 6 Block IIF satellites Sustain constellation

GPS Modernization Program: GPS-III

GPS-III

- **Assess future system level requirements to 2030**
- **System Architecture/Requirements Definition Phase (To be done under a PRDA) - 3, 1 year studies awarded Start FY01**
- **Program Definition / Risk Reduction Phase - awarded Start FY02**
- **Engineering / Manufacturing / Development Phase - awarded Mid FY03**
- **First Launch - NB FY08**

***Risk reduction
Encompass all system requirements
for the long-term***



GPS Modernization Program: Control Segment

Operational Control System (OCS)

- Support Block IIR Modernization testing through two development phases (Legacy, AEP)
- Support Block IIF Modernization testing built on second development phase (AEP)
- System Test Bed to validate signal and prototype UE and support on-orbit testing
- Full operational capability for both Block IIR and Block IIF “lite”

*Evolutionary incremental development
and delivery for increasing capabilities*

GPS Modernization Program: User Equipment

User Equipment

- Continue to field GPS and GPS-aided receivers
- Evolve from “box” to “module” receiver designs
- Develop an open systems architecture to accept modules for future upgrades
- M-code GRAM-SAA SM as the key to incorporate full military Modernization capability
- Continue to invest in and field anti-jam capability

*Open systems architecture
for future evolution*

What does Modernization mean to GPS users?

- **More secure, robust military signal service**
 - Assured acquisition of the GPS signal when needed in a hostile electronic environment
- **Deny an enemy the military advantage of GPS**
 - Protect friendly force operations
 - Preserve peaceful GPS use outside Area of Operations
- **Availability of additional civil GPS signals**
 - Supplement aviation augmentation system's availability