Space and Missile Systems Center

Military GPS User Equipment Modernization

NDIA

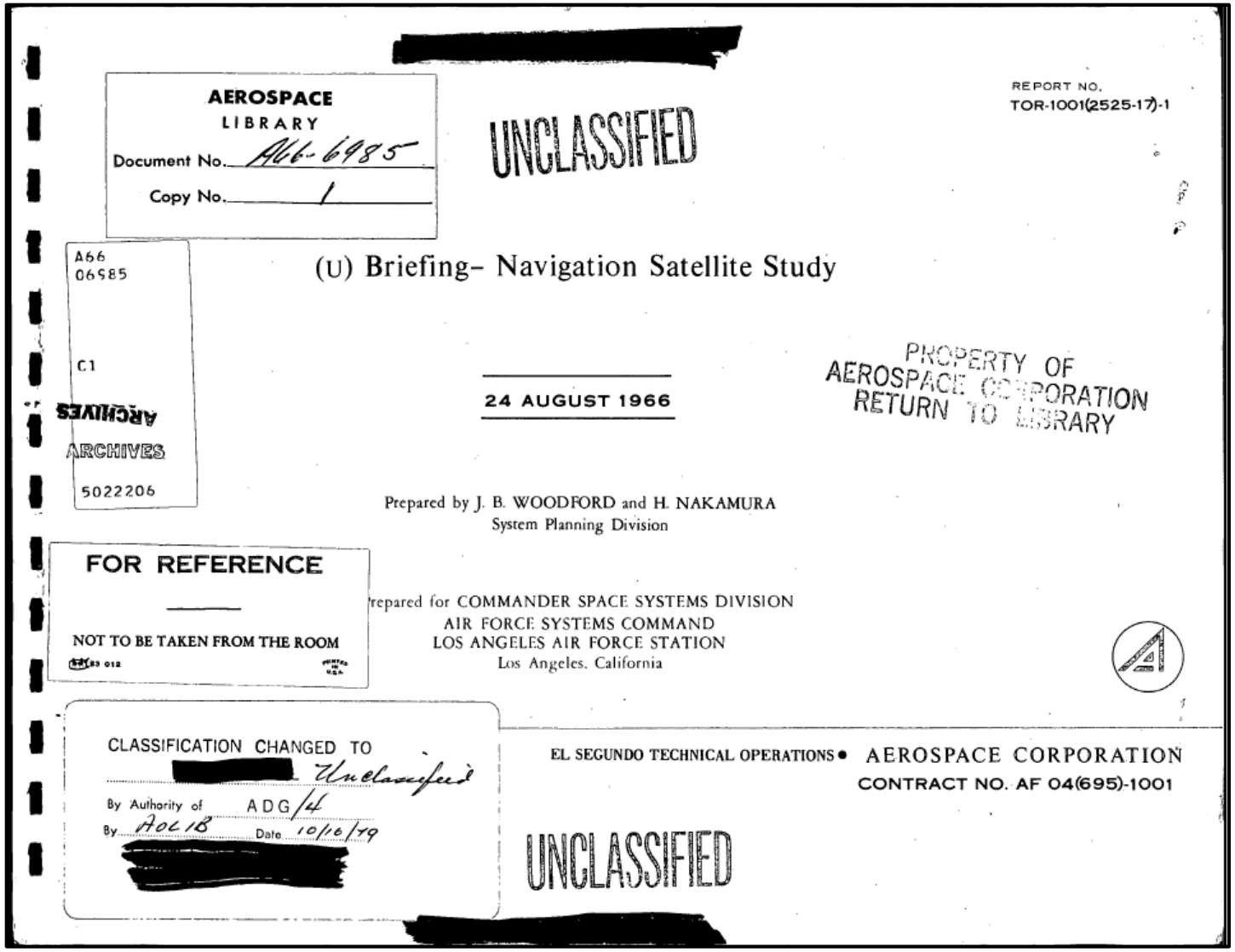
20th Annual Systems Engineering Conference

Col Ed Hospodar

Chief, GPS User Equipment Division

Global Positioning Systems Directorate

1966 Aerospace Corporation "Navigation Satellite Study"



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(U) Briefing– Navigation Satellite Study

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System Planning Division

Prepared for COMMANDER SPACE SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
LOS ANGELES AIR FORCE STATION
Los Angeles, California

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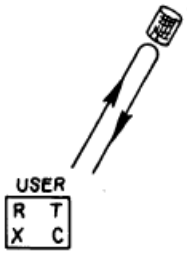
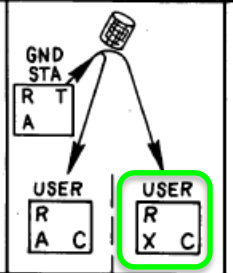
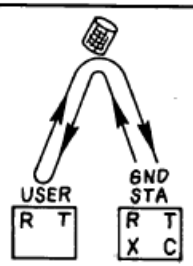
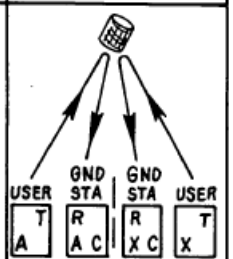
1966 Aerospace Corporation "Navigation Satellite Study"

RANGE AND RANGE DIFFERENCE SYSTEMS

LOCATION OF COMPUTATION	COMPUTATION PERFORMED BY USER		COMPUTATION PERFORMED BY GROUND STATION	
NAVIGATION RADIO LINK	2 WAY	1 WAY	2 WAY	1 WAY
USER EQUIPMENT R = RECEIVER T = TRANSMITTER X = CRYSTAL CLOCK A = ATOMIC CLOCK C = COMPUTER				
APPLICABLE MEASUREMENTS 2 SATS ppḥ 3 SATS ppp 3 SATS ΔPΔPḥ 4 SATS ΔPΔPΔP	✓ (ALTIMETER) ✓	✓(ALTIMETER) ✓ ✓(ALTIMETER) ✓	✓ (ALTIMETER) ✓	✓ (ALTIMETER) ✓ ✓(ALTIMETER) ✓
	USER ACTIVE	USER PASSIVE	USER ACTIVE	USER ACTIVE

- 1-way ranges, passive receivers, crystal oscillators
- Passive (one-way) reduces UE power and avoids detection
- Internal computer spreads the burden for 1,000's of users and avoids sending measurements
- Crystal oscillator minimizes UE SWAP-C and doesn't hurt accuracy
- Autonomous receivers

SWAP-C = Size, Weight, and Power - Cost

The widespread use of GPS and duplication by all other GNSS validate these choices

GPS Overview

Civil Cooperation

- 3+ Billion civil & commercial users worldwide
- Search and Rescue
- Civil Signals
  - L1 C/A (Original Signal)
  - L2C (2nd Civil Signal)
  - L5 (Aviation Safety of Life)
  - L1C (International)

Department of Defense

- Services (Army, Navy, AF, USMC)
- Agencies (NGA & DISA)
- US Naval Observatory
- PNT EXCOM
- GPS Partnership Council

Spectrum

- World Radio Conference
- International Telecommunication Union
- Bilateral Agreements
- Adjacent Band Interference

35 Satellites / 31 Set Healthy
Baseline Constellation: 24 Satellites

Satellite Block	Quantity	Average Age	Oldest
GPS IIR	12	15.7	20.1
GPS IIR-M	7	10.1	11.9
GPS IIF	12	3.6	7.3
Constellation	31	9.7	20.1

AS OF 1 SEP 17

Maintenance/Security

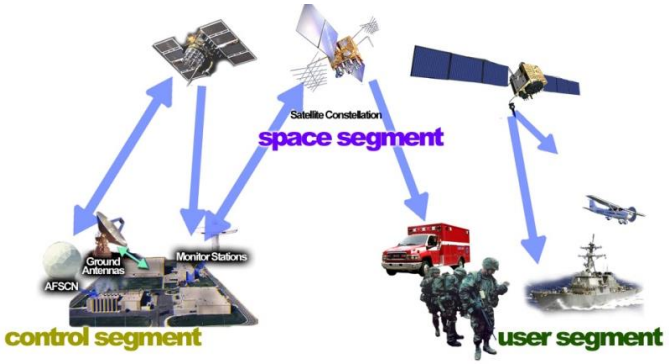
- All Level I and Level II
  - Worldwide Infrastructure
  - NATO Repair Facility
- Develop & Publish ICDs Annually
  - Public ICWG: Worldwide Involvement
  - Materials Available at: gps.gov/technical/icwg
- Update GPS.gov Webpage
- Load Operational Software on over 970,000 SAASM Receivers
- Distribute PRNs for the World
  - 120 for US and 90 for GNSS

Department of Transportation

- Federal Aviation Administration

Department of Homeland Security

- U.S. Coast Guard



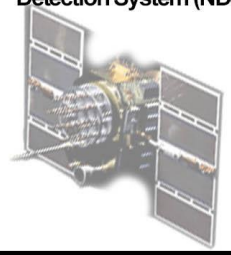
International Cooperation

- 57 Authorized Allied Users
  - 25+ Years of Cooperation
- GNSS
  - Europe - Galileo
  - China - Beidou
  - Russia - GLONASS
  - Japan - QZSS
  - India - NAVIC

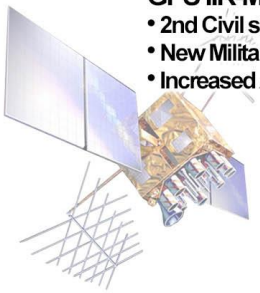
GPS Modernization

Space System (Satellites)

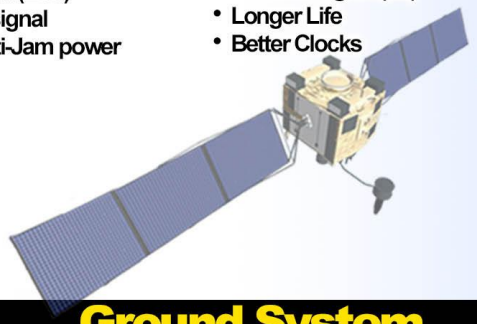
Legacy (GPS IIA/IIR)
- Basic GPS
- NUDET (Nuclear Detonation) Detection System (NDS)



GPS IIR-M
- 2nd Civil signal (L2C)
- New Military signal
- Increased Anti-Jam power



GPS IIF
- 3rd Civil Signal (L5)
- Longer Life
- Better Clocks



GPS III (SV01-10)
- Accuracy & Power
- Increased Anti-Jam power
- Inherent Signal Integrity
- Common L1C Signal
- Longer Life

GPS III (SV11+)
- Unified S-Band Telemetry, Tracking & Commanding
- Search & Rescue (SAR) Payload
- Laser Retroreflector Array
- Redesigned NDS Payload
- Regional Military Protect (RMP)

Ground System

Legacy (OCS)
- Mainframe System
- Command & Control
- Signal Monitoring

AEP
- Distributed Architecture
- Increased Signal Monitoring Coverage
- Security
- Accuracy
- Launch And Disposal Operations

OCX Block 0
- GPS III Launch & Checkout

GPS III Contingency Ops (COps)
- GPS III Mission on AEP

M-Code Early Use (MCEU)
- Operational M-Code on AEP

OCX Block 1
- Fly Constellation & GPS III
- Begin New Signal Control
- Upgraded Information Assurance

OCX Block 2+
- Control all signals
- Capability On-Ramps
- GPS III Evolution

User Equipment System (Receivers)

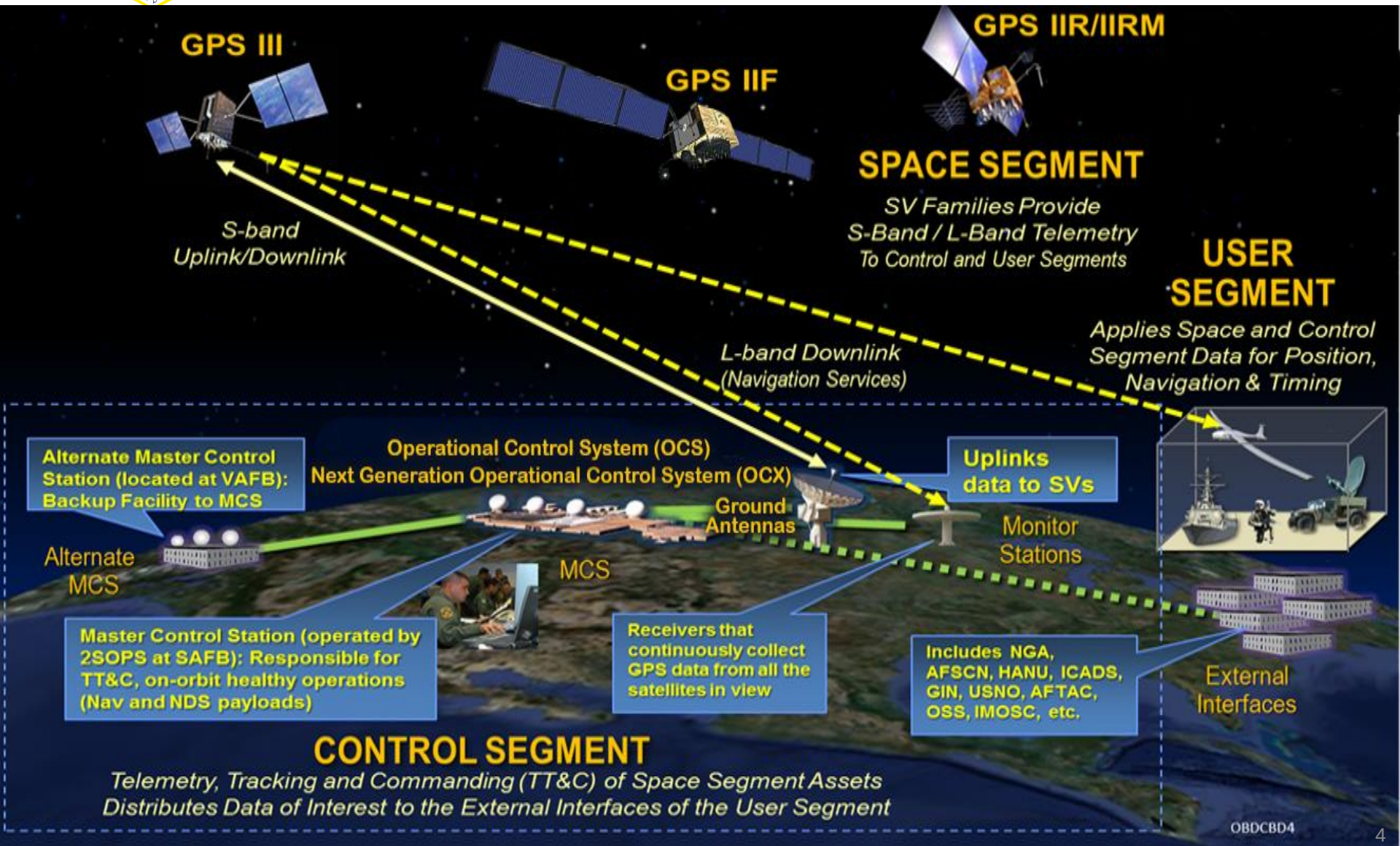
Legacy (PLGR/GAS-1/MAGR)
- First Generation System

User Equipment
- Improved Anti-Jam & Systems
- Reduced Size, Weight & Power

Upgraded Antennas
- Improved Anti-Jam Antennas

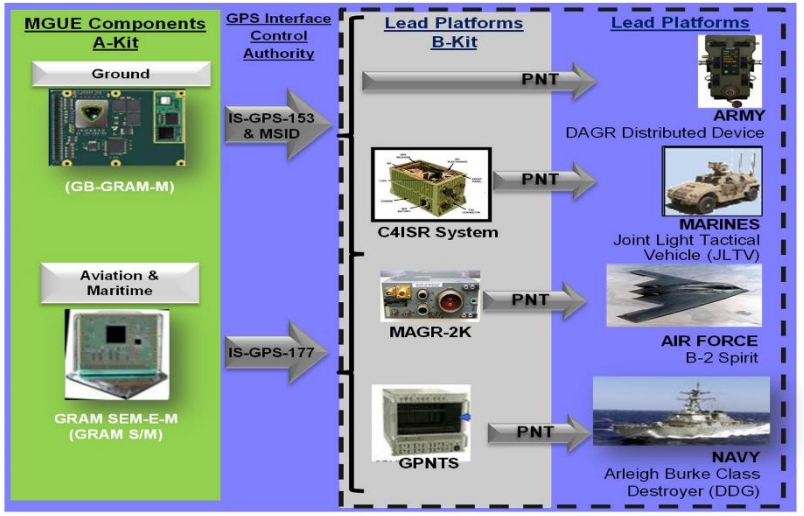
Modernized
- M-Code Receivers
- Common GPS Modules
- Increased Access/ Power with M-Code
- Increased Accuracy
- Increased Availability
- Increased Anti-Tamper/ Anti- Spoof
- Increased Acquisition in Jamming

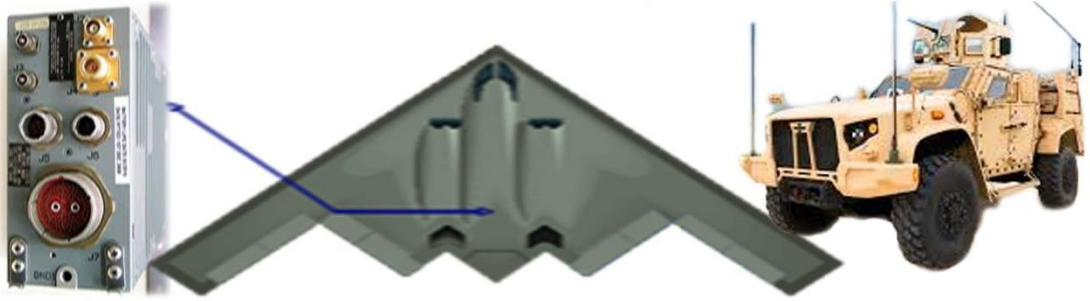
GPS Enterprise Operational View



Military GPS User Equipment (MGUE)

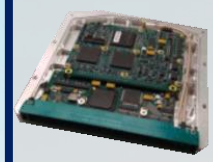
- Commercial market-driven acquisition approach
- Three vendors developing modernized receiver cards
  - Ground form factor
  - Aviation/Maritime form factor
- Current Status
  - L-3 Technologies first to receive security certification Oct 2016
  - Developmental testing ongoing
  - Conducting early integration activities to support Service-nominated Lead Platforms





Military GPS User Equipment

Prototype GPS Receiver Flight Tested on B-2



Prototype Military GPS User Equipment Receiver Card

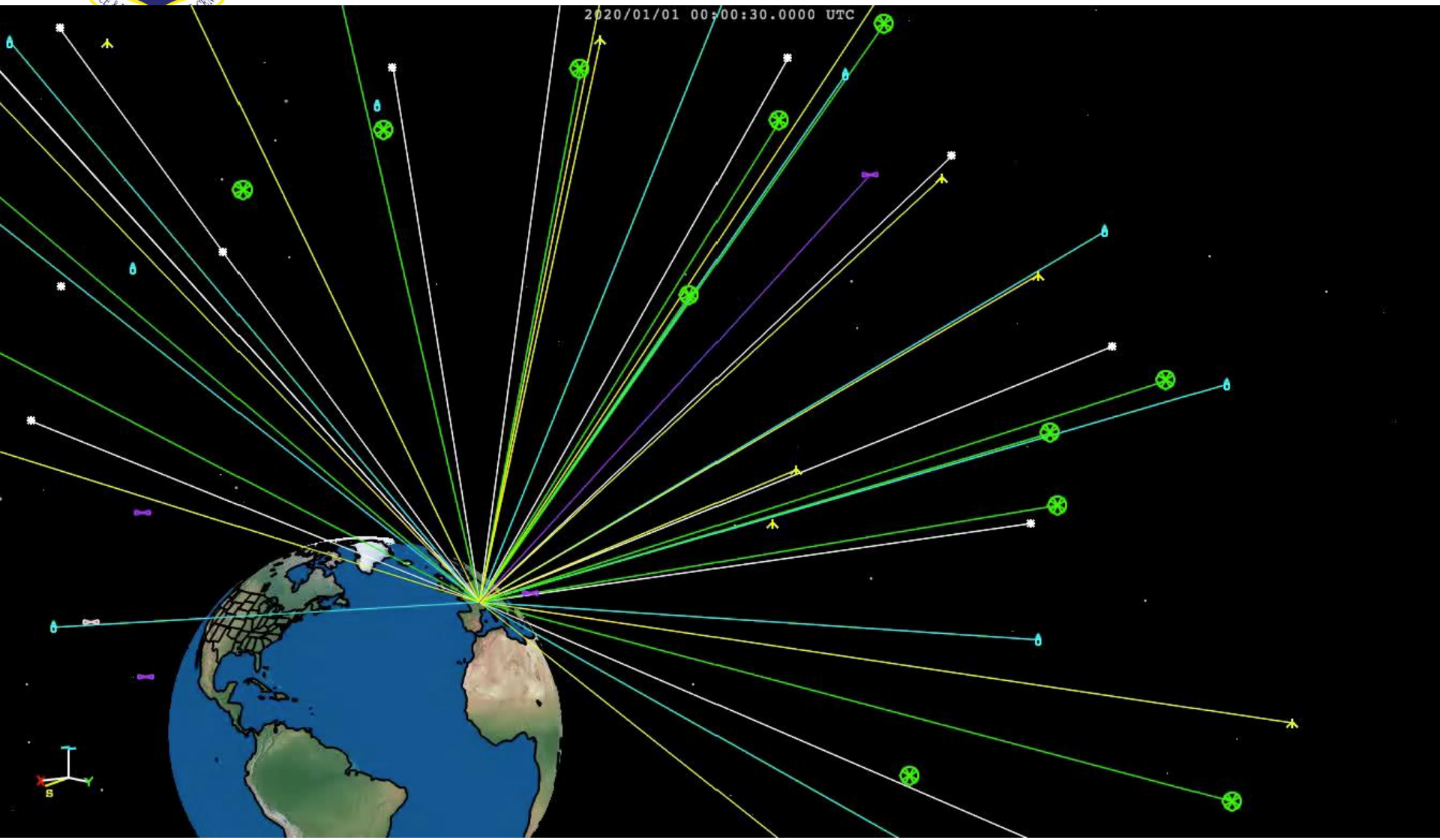
Prototype Miniaturized Airborne GPS Receiver

4 Successful B-2 Test Flights

Military GPS User Equipment Demonstrated in B-2

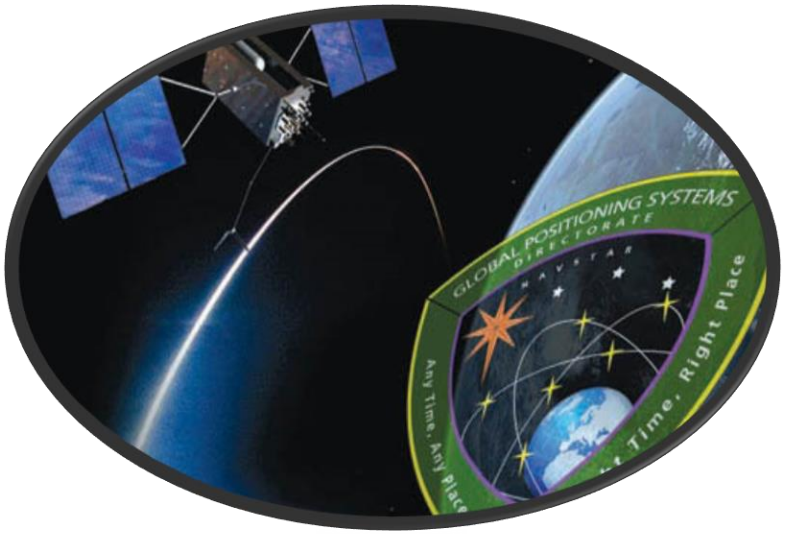
MGUE Precision Guided Munitions Test

Looking Ahead: Multi-GNSS



Perspectives

- GPS is the Global Utility
  - Committed to maintaining uninterrupted service
  - "The Gold Standard"
- Modernizing to enhance GPS resiliency by:
  - Upgrading all three segments
  - Moving to M-Code
  - Adding civil signals
- Exploring multi-GNSS potential



Deliver capabilities, execute with excellence, lead with transparency