

Int'l Global Navigation Satellite Systems Society (IGNSS)
2009 symposium
November 30th – December 3rd, 2009

GPS Modernization:

On the Road to the Future

GPS IIR/IIR-M and GPS III

Michael Shaw
Director, Navigation Systems
Global Business Development
Lockheed Martin Space Systems Company





Overview



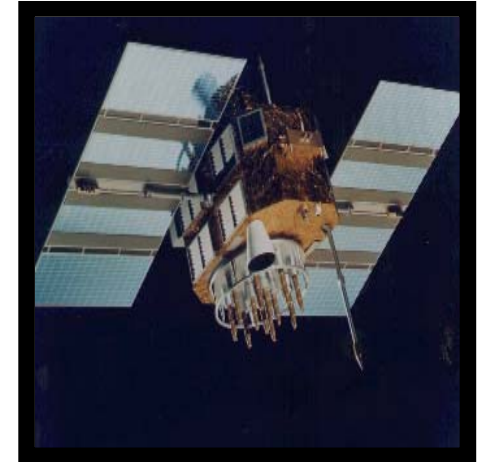
- **GPS Modernization**
- **GPS IIR/IIR-M**
 - SVN-49
- **GPS IIIA**
- **The Road Ahead**



GPS Operational Constellation



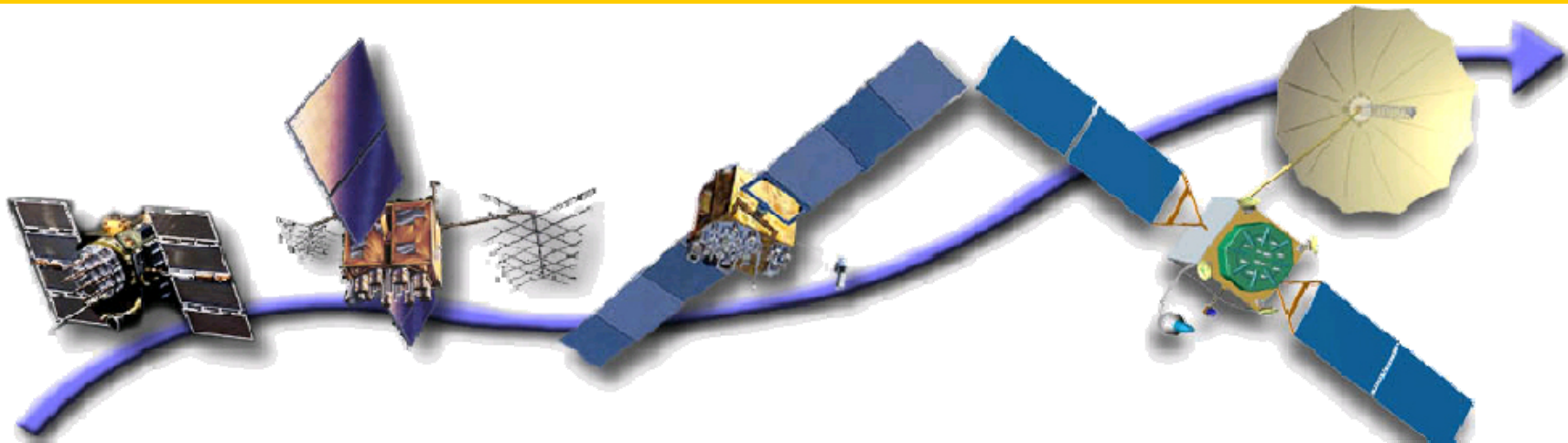
- GPS satellites provide continuous navigation signals on two L-band frequencies, L1 and L2
 - Baseline constellation is 24 satellites
- Current GPS constellation consists of 30 operational satellites (As of 28 November 2009)
 - 11 Block IIA satellites
 - 19 Block IIR satellites (Includes 7 IIR-M satellites)
 - 3 additional inactive “spares”
- GPS Modernization Program in progress now



GPS IIR/IIR-M comprise two thirds of current operational constellation



GPS Modernization



Increasing System Capabilities ♦ Increasing Defense / Civil Benefit

Block IIA/IIR Block IIR-M, IIF Block III

Basic GPS

- **Std Service (16-24m SEP)**
 - Single frequency (L1)
 - Coarse acquisition (C/A) code navigation
- **Precise Service (16m SEP)**
 - Y-Code (L1Y & L2Y)
 - Y-Code navigation

IIR-M: IIA/IIR capabilities plus

- 2nd civil signal (L2C)
- M-Code (L1M & L2M)
- Anti-jam flex power

IIF: IIR-M capability plus

- 3rd civil signal (L5)
- Anti-jam flex power

Block IIIA:

- Increased anti-jam power
- Increased security
- Increased accuracy
- Navigation surety
- Backward compatibility
- Assured availability
- Controlled integrity
- System survivability
- 4th civil signal (L1C)



GPS Space Segment Modernization



- **Lockheed designed and built 21 GPS IIR satellites**
 - **1st successful IIR launch, 22 Jul 1997; 12 IIRs currently operational**
 - **1st IIR-M launch, 25 Sep 2005; 7 IIR-Ms currently operational**
 - **Includes new 2nd civil signal (L2C) and M-Code capabilities**
 - **IIR-20(M), SVN-49, launched 24 Mar 2009; not yet available to users**
 - **Included demonstration of the 3rd civil signal, the L5**
 - **GPS IIR-21(M) launched on 17 August 2009; last GPS IIR-M satellite**
- **In May 08, Lockheed selected to design and produce GPS IIIA**
 - **Initial contract for 2 GPS IIIA satellites with options for 10 production satellites**
 - **Growth potential to support capability insertion program for IIIB/ IIIC**

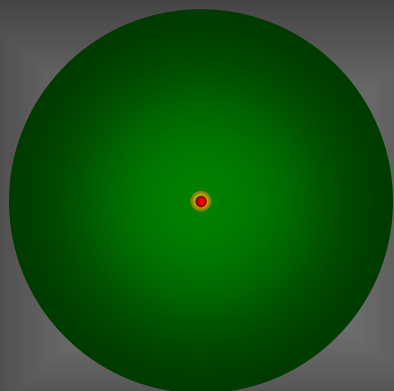


GPS IIR/IIR-M Performance

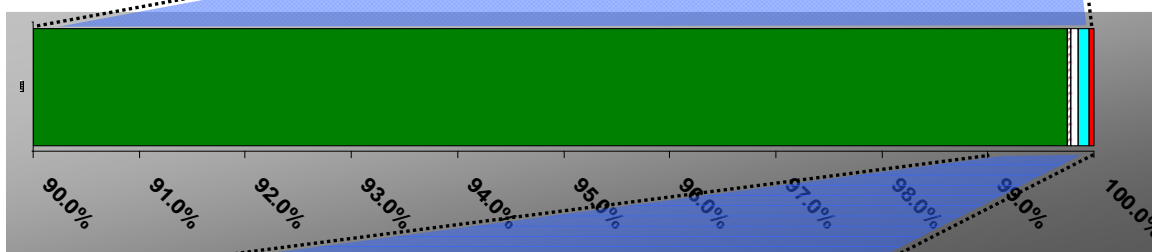
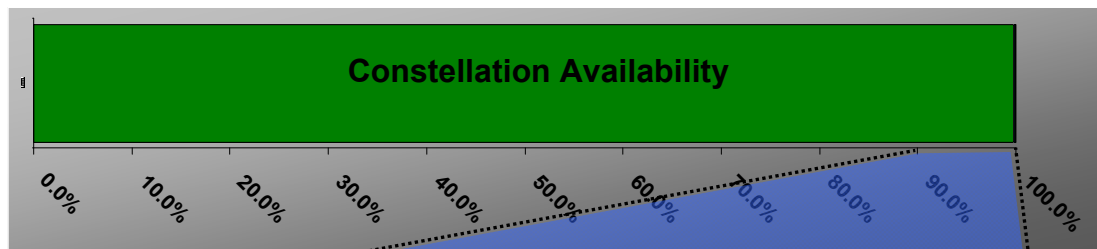
Availability



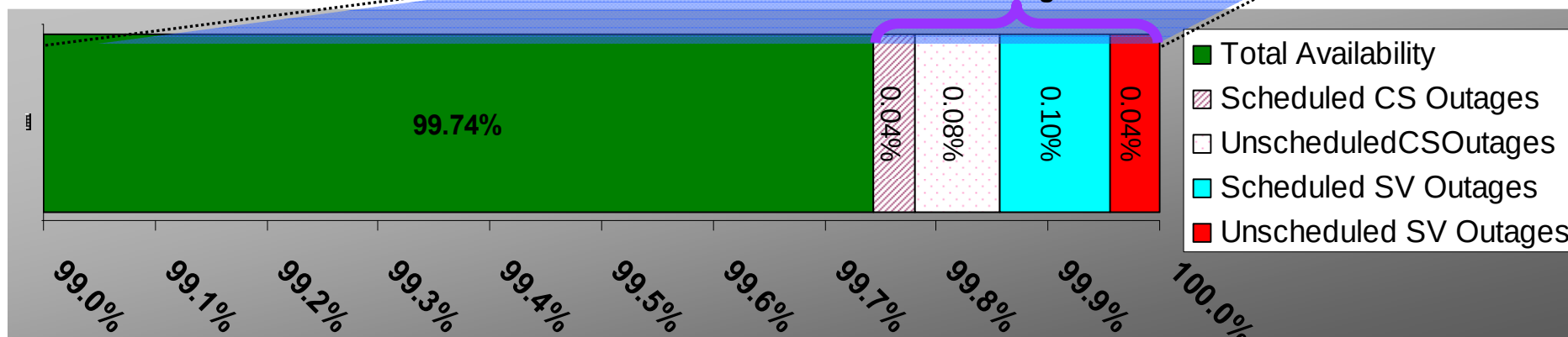
IIR Outage to Operational Ratio



Yellow Circle is Total Outage Time
Red is Unscheduled SV Outage Time



Total Outage Time



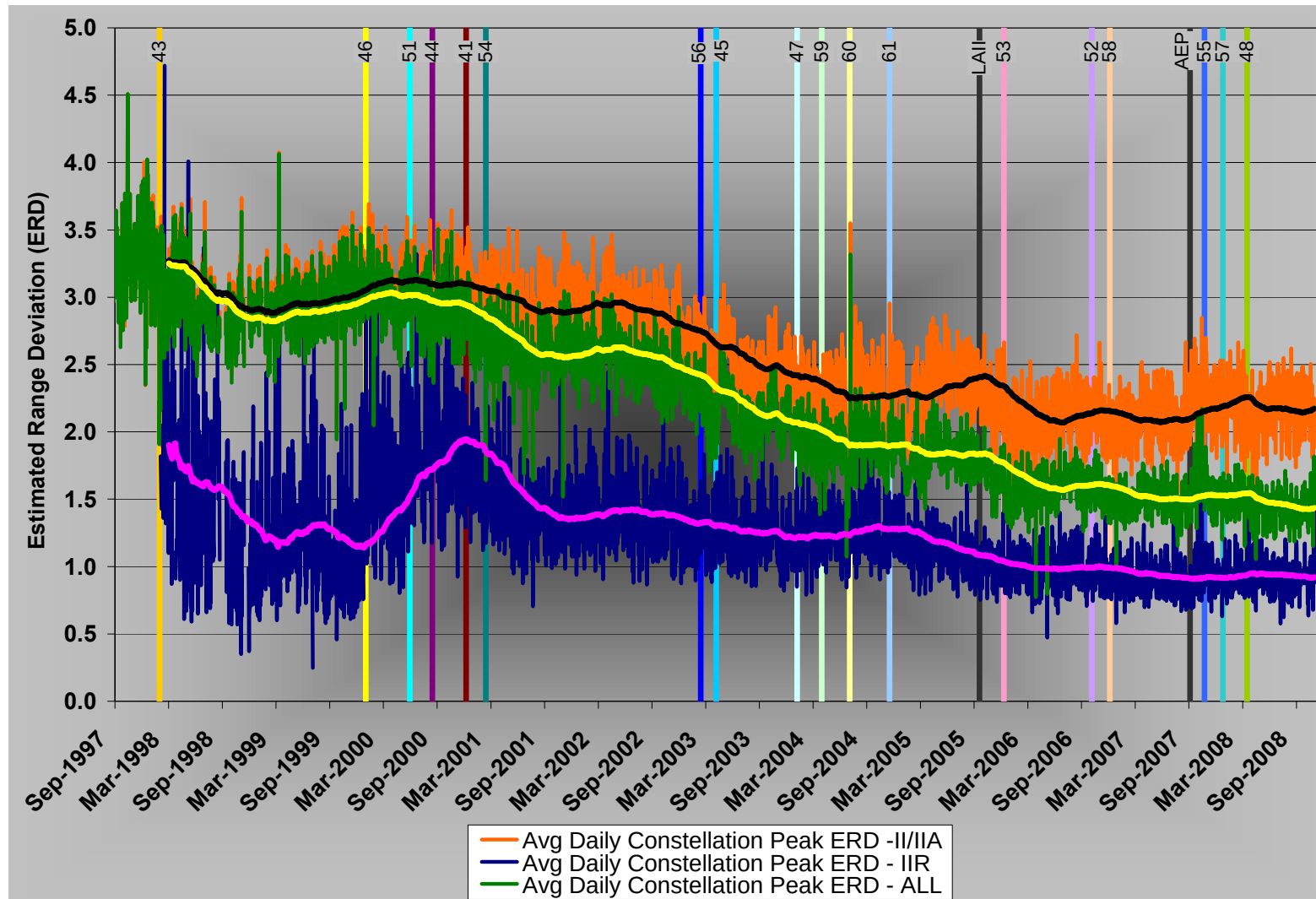
IIR SV Lifetime Navigation Availability greater than 99.7%

100 years of successful IIR/IIR-M on-orbit operations as of May 09



GPS IIR/IIR-M Performance

Lifetime Estimated Range Deviations (ERDs)



Growing GPS IIR/IIR-M constellation consistently decreasing user error



SVN-49 - Signal Chronology



- **Air Force acted to preserve spectrum filing with International Telecommunication Union (ITU) for L5, the 3rd civil signal**
 - **Required the signal begin operating from space by 26 Aug 2009**
- **Lockheed awarded contract in April 2007 to develop and integrate a payload to provide an on-orbit demo of L5 signal**
 - **Action was taken to mitigate risk of possible IIF launch delay**
 - **Work was completed less than a year after contract award**
- **IIR-20(M) was launched 24 March 2009**
- **The L5 demonstration payload was powered on 10 April 2009**
 - **Successfully brought the L5 frequency spectrum into use**
 - **L1, L2 signal distortion detected shortly after payload activation**



SVN-49 - Signal Chronology



- **Root cause established**
 - **Caused by signals reflecting off L5 filter and transmitted through satellite antenna**
- **Overall effect is a permanent, static multipath signal being generated within the satellite**
 - **Effects are most prominent on the portion of antenna whose influence is greatest at high elevation angles**
 - **Signal distortion is user elevation angle dependent, with little or no distortion at low elevation angles**
- **Meets GPS SPS and PPS Performance Standards**



Key Considerations for Way Forward



- **No consensus from user equipment (UE) manufacturers**
 - **Updating software in fielded UE very challenging**
 - **Some UE may be impossible to update**
- **SVN-49 remain “unhealthy” until mitigations in place**
 - **Allows time to develop and implement Control Segment and/or Civil/Military receiver mitigations**
 - **Intend to set SVN-49 healthy; not if but when**
- **Constellation is very robust today**
 - **Can take a long term focus in developing the mitigation**



GPS III Overview



● *Next Generation GPS*

- Improved performance for both war-fighter and civilian users
- Superior system security, accuracy, and reliability

● *Strategic Teammates*

- U.S. Air Force (Los Angeles, CA)
- LM Space Systems Company (Newtown, PA)
- ITT Corporation (Clifton, NJ)
- General Dynamics (Scottsdale, AZ)

● *Heritage of Success*

- GPS IIR/IIR-M success
- Time-tested A2100 bus

Low risk solution to satisfying on-going GPS modernization



GPS III



- **Provide new critical high-value GPS space capabilities; constellation sustainment**
 - Improved accuracy and power for both military and civilian users
 - Additional 4th civil signal (L1C)
 - Enhanced M-code Earth Coverage power
- **Deliver a high-confidence acquisition**
 - "Back to Basics" program execution
 - Time-certain development for on-time launch availability
- **Avoid previous space program acquisition problems**
 - Unnecessary technical, cost and schedule risks
 - Cost overruns and schedule delays
- **Graceful growth path for inserting possible future capabilities (GPS IIIA → IIIB → IIIC)**

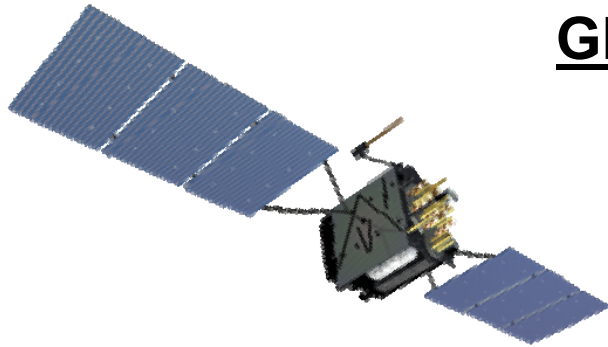


Artist conception of GPS IIIA vehicle

Low risk solution to satisfying on-going GPS modernization



GPS III Capability Insertion

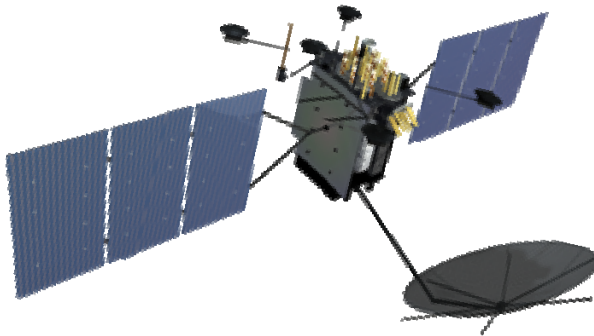
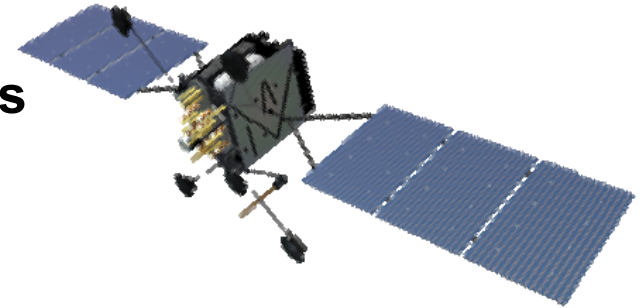


GPS IIIA (8 planned)

- Increased accuracy (0.63 m spec)
- Increased Earth Coverage Power
- Additional civil signal (L1C)
 - Interoperable with Galileo and Japan's QZSS
- Bus capacity for IIIB and IIIC

GPS IIIB (8 planned)

- Real-time command and control cross-links
 - Allows upload of satellites via single contact
 - Improves constellation accuracy



GPS IIIC (16 planned)

- High-power spot beam
 - Provides increased anti-jamming capability for military

Flexible transition and content of future blocks reduces program risk



- **A2100 modular design accommodates wide range of payloads and launch vehicles**
 - Increased on-orbit reliability
 - Features parts reduction/simplified construction
 - Proven production cycle time
 - Exceptional earth pointing reliability
- **Thirty-eight A2100s on-orbit today**
 - 1st A2100 in operation for over 13 years
 - No satellite vehicle failures after over 250 spacecraft-years accumulated to date
 - Received an Award for Satellite Reliability as the “Most reliable and efficient of its class”
 - Key customers:

SES World Skies	Echostar	Telesat
SES ASTRA	SPJSAT	BSAT
US Air Force	US Navy	NASA

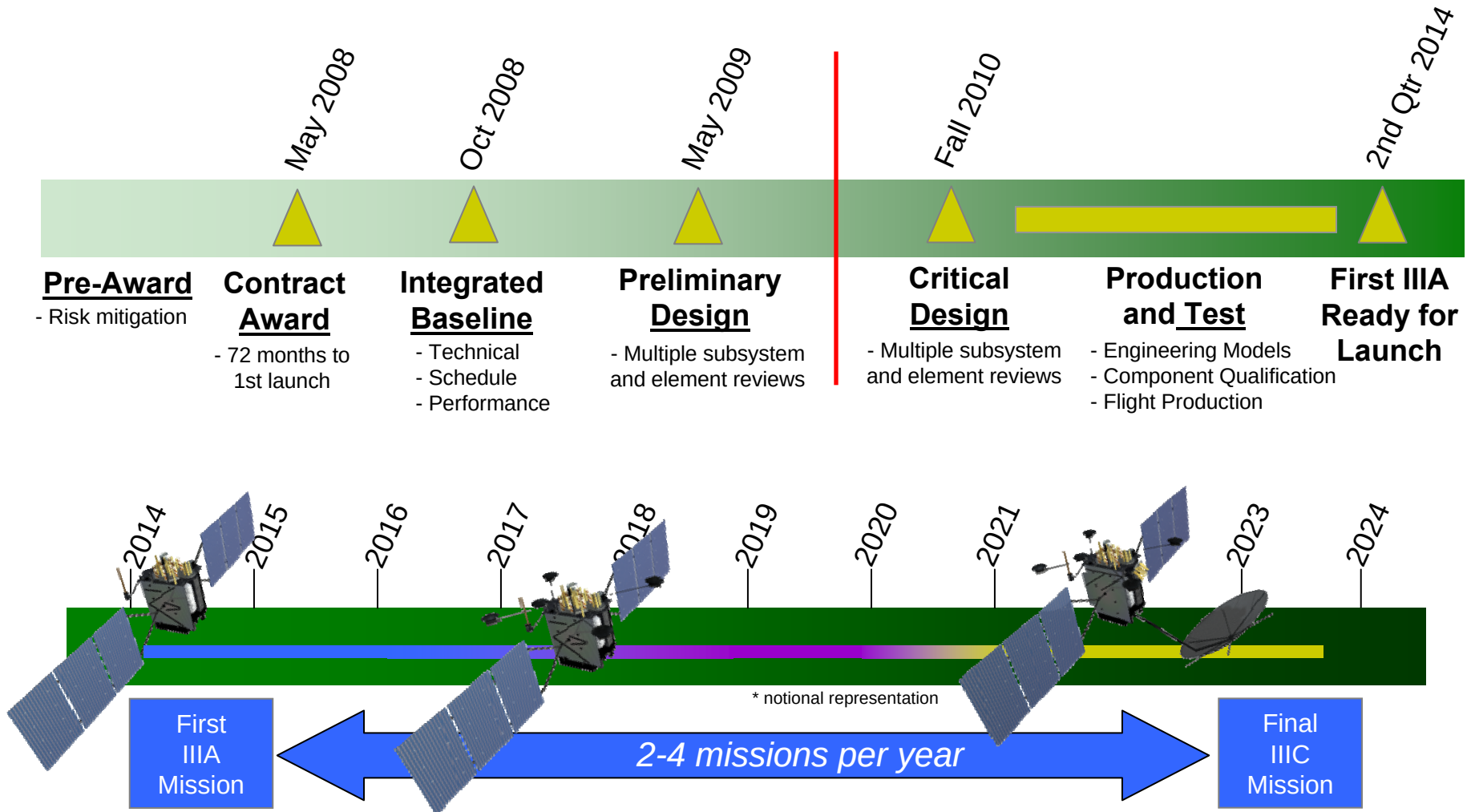


A2100AX vehicle at Newtown facility

GPS III built on highly reliable and adaptable satellite bus platform



GPS III Schedule



Preliminary Design Assessment – May 2009:
Program On-cost, on-schedule, meets/exceeds all technical specs



The Road Ahead



- **GPS modernization is in progress**
 - New GPS signals for both military and civil users
- **GPS IIR/IIR-M generation complete**
 - More than 100 years successful on-orbit performance
 - Currently comprises two thirds of on-orbit GPS constellation
 - Foundation of GPS constellation for a number of years to come
- **GPS III generation is coming in 2014**
 - Program is on schedule and successfully moving forward
 - Will bring new capabilities for global users
 - Compatible and interoperable with other international systems such as European Galileo and Japan's QZSS

Thank you

