



Considerations for Constellation Sustainment

Brief to National PNT Advisory Board

9 November 2011

v5



Maintaining the current level of GPS Services

What are the challenges?

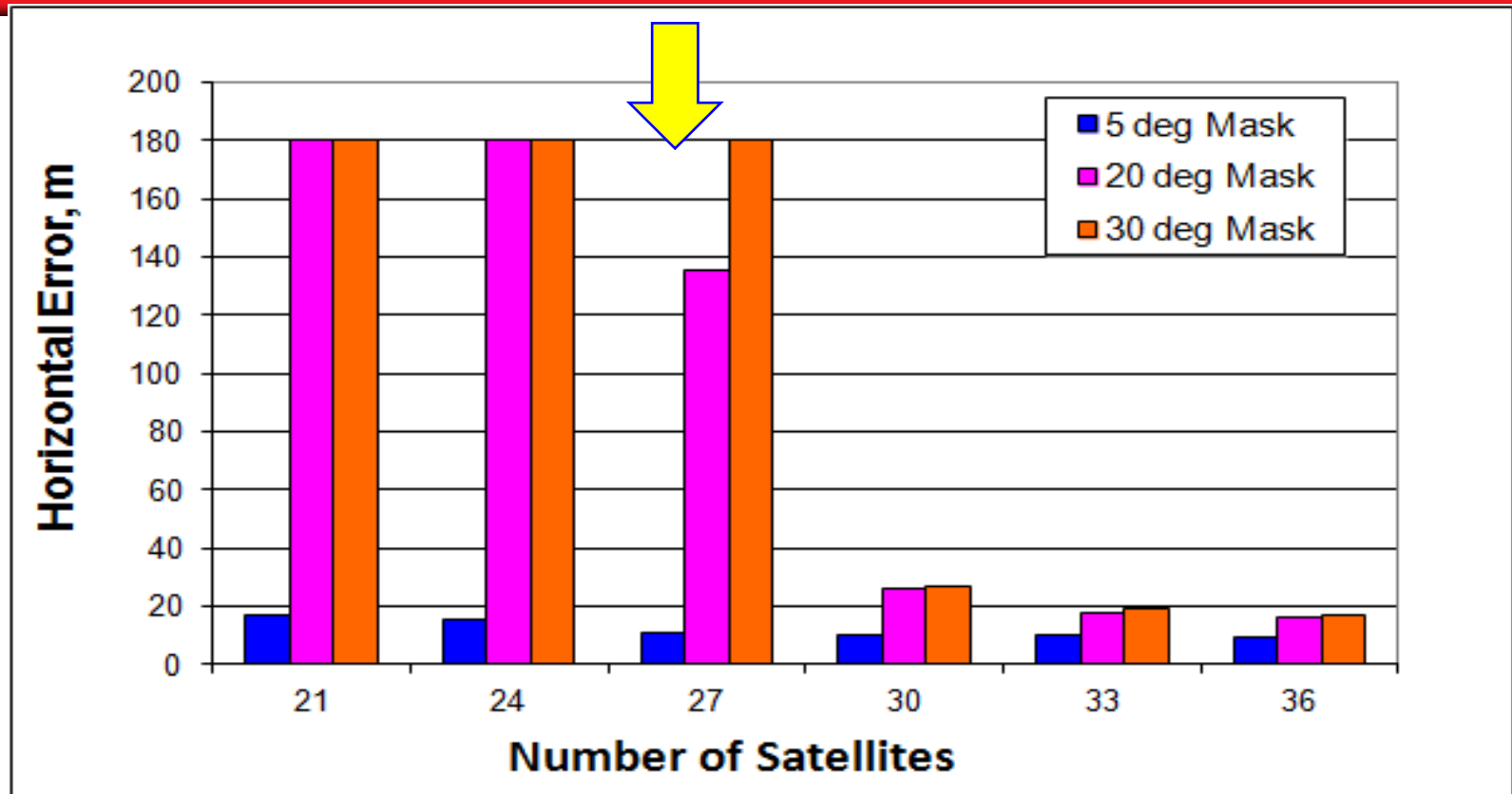
**What are the opportunities to
Mitigate?**

What has been Analyzed

Examined alternate means of delivering global GPS positioning, and time services (GPtS)

- Maintain current level of service & enable improved service***
- Considered different orbits, platforms, & signal sources***
- Remain within context of GPS III program & budget***
- Consider impact on cost of launch***

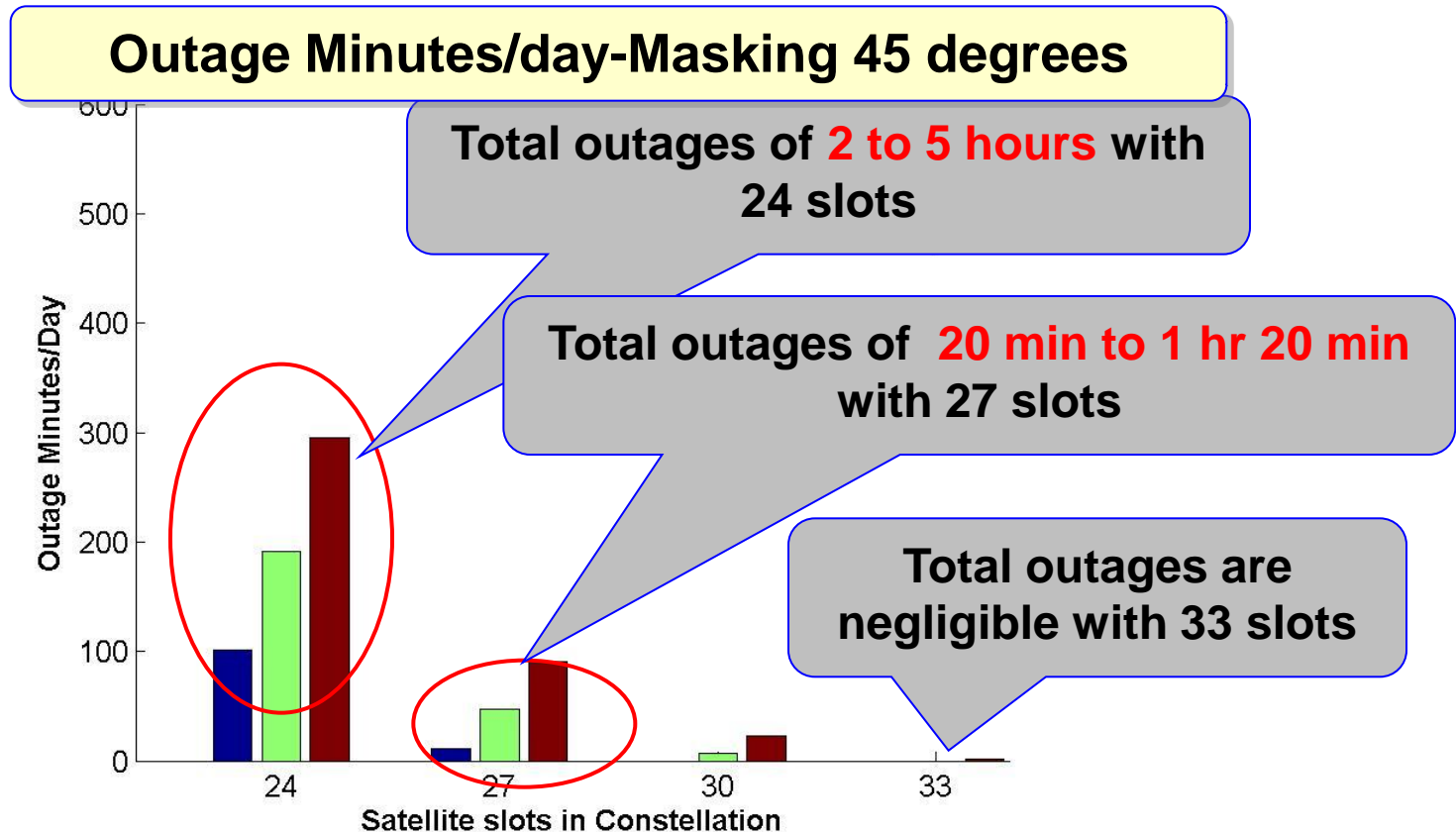
What is required for the future?



**Dramatic Improvement in Availability of Accuracy
with 30+ SVs**

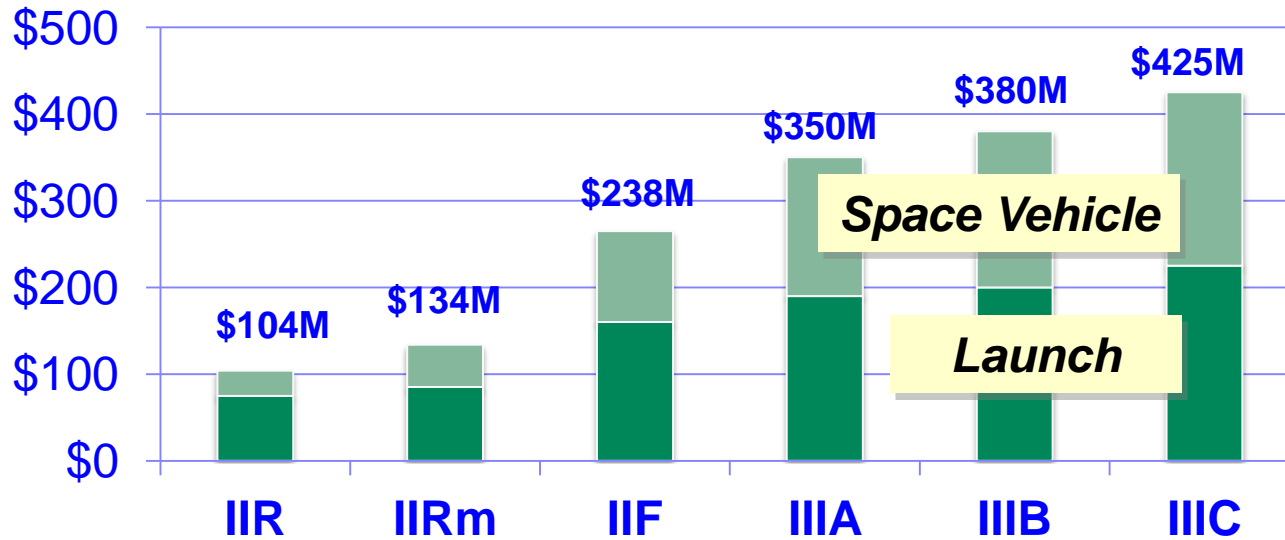
First Measure of Effectiveness-Availability

(Unavailability of GPS due to Constellation size and Terrain or Buildings)



On Orbit Costs

(Approximate & Estimated)



Current Program not Sustainable

Options Examined

GEO

- *GPS III boosted to GEO*
- *Hosted GPS III payload on commercial GEO of opportunity*
- *Hosted transponder payload on commercial GEO of opportunity*
- *Partner with other agencies' GEOs (e.g., FAA, NASA) to add GPS signals*

MEO

- *GPS III dual-launched*
- *GPS Spartan (GPS III w/o other payloads), dual launched*
- *GPS Limited (less than full signal set)*

LEO

- *Hosted GPS III (partial) or transponder payload*
- *Used as near-band pseudolites or signals of opportunity*

Non-space

- *Pseudolites (terrestrial & airborne)*
- *eLoran & signals of opportunity*

Analysis Criteria

- ☞ **Service performance attributes**
 - *Assured availability (geometry), accuracy, anti-jam (AJ, signal power), bounded inaccuracy, integrity*
- ☞ **Technical issues**
 - *Integration of payload, plus control of payload & satellite*
 - *Space, weight, & power, plus cost (SWaP-C)*
 - *Configuration & launch options*
 - *User equipment impacts*
- ☞ **Scheduling issues**
 - *Hosted ride opportunities & constraints*
 - *Business case for hosted secondary payloads*
- ☞ **Other issues**
 - *Policy*
 - *Vulnerabilities & risks*
 - *Other agency interests user equipment impacts*

Overview

- ☞ **Potential & realistic GEO & MEO options**
 - *Used individually or in combination*
 - *Enable timely implementation of new capabilities & services*
 - *Challenges: timing/availability, location, & operational control*
 - *FAA’s “WAAS-enabled” algorithms to enable GEO tracking in UE*
- ☞ **Feasible LEO options – eliminated from further discussion**
 - *Requires major new operational & ground infrastructure*
 - *Require new or significantly upgraded user equipment*
 - *Limited benefit in comparison to GEO & MEO options*
- ☞ **Other options – eliminated from further discussion**
 - *Require new ops concepts, new ground infrastructure, or both*
 - *Benefit limited geographic area; visibility & shading challenge*
 - *Some interesting concepts that require more study & test data*

GEO-MEO Findings

1 GEO = 3 MEOs

- *2 GEOs, separated by about 15° or more longitude, almost same as adding 6 MEOs*

Today GEOs provide civil (L1 & L5) signals

- *FAA's WAAS provides 2 (3) in US National Airspace System*
 - ◆ *In Western Hemisphere, provides redundant 2-GEO coverage*
 - ◆ *For foreseeable future (until 2040 ... or longer)*
- *Other nations & regions provide/plan WAAS-equivalent services*
 - ◆ *Europe's EGNOS (3 GEOs), Japan's MSAS (2 GEOs), India's GAGAN (at least one GEO planned), potentially others*

Replacement GEOs could broadcast civil and military

- *NASA's TDRSS could add L-band beginning mid-late 2010s*

GEO-MEO Analyzed Options

GPS III GEO

- *GPS III payload hosted on commercial GEO of opportunity*
- *GPS III boosted to GEO*
- *GPS III payload on custom GEO bus (“Spartan” GEO)*

GPS III MEO

- *Continue GPS III program as currently planned*
 - ◆ *Dual-launch capable by SV 5-6, weight reduction in SV 9+*
- *GPS III payload on custom MEO bus (“Spartan” MEO)*

Launch options

- *EELV & GPS III – dual-launch MEO, single-launch GEO*
- *EELV & Spartan – multiple launch MEO or GEO*
- *Commercial (eg, Falcon 9) & GPS III – single-launch MEO*
- *Commercial & Spartan – multiple launch MEO or GEO*

Baseline Assumptions

- ☞ **2016 GPS constellation continues operating in “Expanded 24” (27-slot) configuration**
 - *Ready for expansion to 30 slots or equivalent*
- ☞ **Baseline constellation includes**
 - *GPS III (4), IIF (12), IIR-M (7), IIR (4) in 27 primary slots*
 - *With remaining useful IIR-M & IIR (≤ 9 total) in residual slots*
 - *27 operational & up to 9 residual, plus 4 GPS III (under contract) SVs with NDS capability*
- ☞ **Alternate architectures deployable beginning 2016**

Recommendations

- ☞ **Expand capability to 30 slots (or equivalent) utilizing alternate constellations**
 - *Beginning no later than 2016*
- ☞ **Develop GPS III Spartan (dual launch able GPS Nav-payload only)**
 - ☞ *Prepare for MEO or GEO (slight modification to antenna)*
- ☞ **Continue GPS III as planned (SV 9+)**
 - ☞ *But more aggressive weight reduction & smaller bus*
 - ☞ *If keeping NDS, no more than IIR SWaP, including antenna*
- ☞ **Prepare & stage GPS navigation payloads (1-3) for hosted rides**
 - ☞ *Integration plans for ½ payload panel all US std GEO buses*
- ☞ **Partner with FAA & NASA for improved GEO services**
 - ☞ *Take advantage of increased geometry with addition to next generation NASA TDRSS SVs*
 - ☞ *Broadcast all civil signals from WAAS and work for other SBASs' GEO systems to provide the same*

Implementation

GPS-Based MEO-GEO Service 2016+

- **Retain Expanded 24 (27 slot) MEO constellation**
 - *Sustain with GPS III & Spartan MEO (multiple launch)*
- **Use ranging signals from WAAS & other GNSSs' SBAS**
 - *SBAS provide L1 & L5 civil signals in GEOs' downlink coverage*
 - *Adds “30-MEO-equivalent” geometry for US & global civil users*
- **Increased coverage for civil & military where needed with GEOs**
 - *Provides for 30-MEO-equivalent geometry where/when needed*
 - *Work with FAA to add L2 to WAAS (over Homeland AOR)*
 - *Seek opportunity(ies) for hosted ride GEO(s) when available*
 - ◆ **E.g., satellite TV over Africa**
 - *Boost GPS III or Spartan to GEO in other needed location (s)*
 - ◆ **E.g., initially of SW & SE Asia, plan to move as needed**

Bottom Line

Opportunities exist to sustain & potentially provide increased capabilities & service at the same or lower on-orbit costs than current GPS III Program.

- These can be provided through a range of different configurations & orbits*
- Dual-launch becomes a significant need for reducing on orbit costs and insuring sustainment of current level of service.*
- Development of a “Spartan GPS Only Satellite that is dual- launch capable with ability to be flown at both MEO and GEO satellite is needed for sustainment and increased capability*
- FAA WAAS broadcasting all civil signals provides considerable improved service in North America*
- NASA TRDSS provides opportunity to improve service globally*

Final note: JFCC Space has plans to turn on orbit residual Satellites should there be a significance decrease in service performance.

Questions