ITT

SATNAV Backup Study

For NGATS Institute

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“Roadmaps to Success”

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Engineered for life

Presentation Overview

- Objectives of the Satellite Navigation Backup Study
- Overview the future aviation environment
  - Capabilities of Next Generation Air Transportation System
    - Navigation perspective
  - Enabler: Modernized GPS and GNSS
- Two main aspects of the study
  - Determine Requirements and Conduct Analysis
    - Technical, Functional, Life Cycle Cost
  - Stakeholder input - ‘Voice of the Customer’

Objectives and Scope of this Study

- Objectives
  - Develop a set of potential alternative backup Area Navigation solutions for NGATS that:
    - Meet specified navigation requirements
      - Functional and performance
    - Accommodate "Voice of the Customer" (especially Users) needs
    - Are cost effective
    - Are available world-wide (Goal)
  - Define and evaluate alternatives to develop recommended solutions
- Scope
  - Define SATNAV Backup System solutions for milestone dates (2015, 2020, and 2025)
  - Solution set is to encompass a broad range of backup possibilities and assume SATNAV as the primary means of navigation

The NextGen Planning for the 21st Century

PNT Services Capabilities

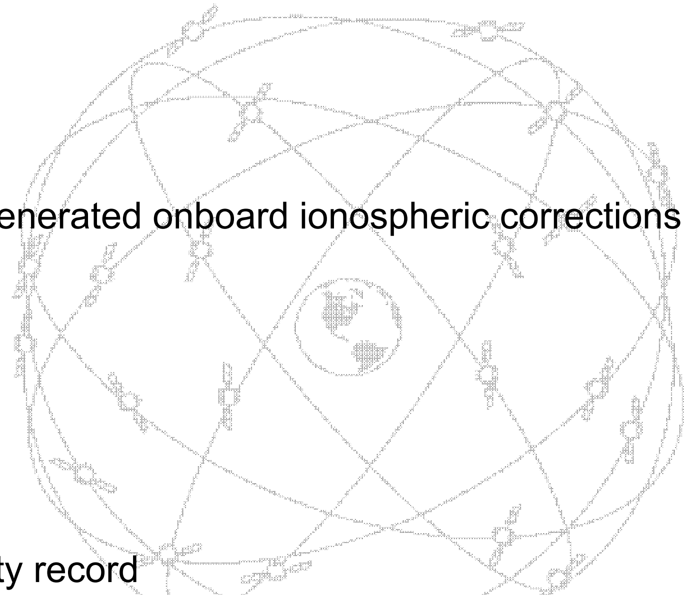
PNT Services Capabilities enabled by Satellite Navigation

- Air routes are independent of the location of ground-based NAVAIDs
- Area Navigation (RNAV) is used throughout the NextGen NAS; RNP is used where required in order to achieve system objectives, which reduce controller workload and increases efficient use of NAS resources (airspace and runways)
- Increased availability of lower minimum, guided approaches at smaller airports (mostly General Aviation)
- Reduced cost in providing better navigation services

Determine Future Operational Environment – GPS/GNSS

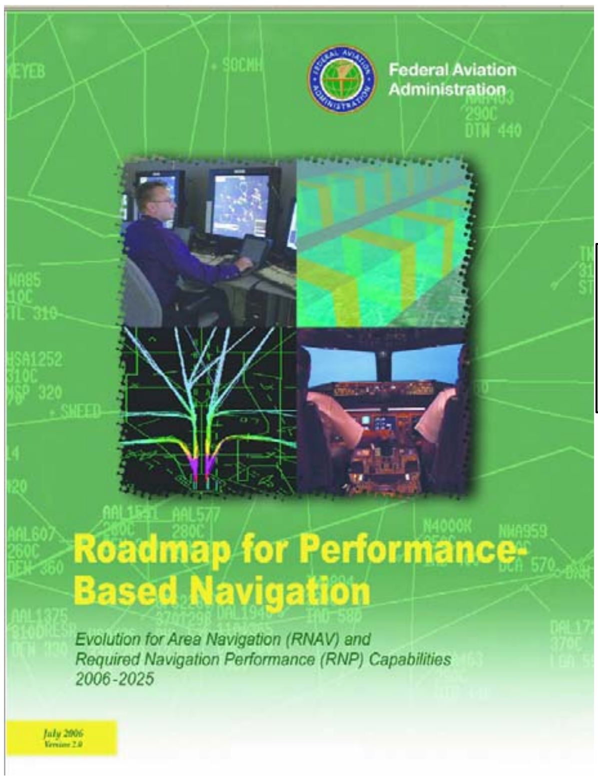
- **Identify GPS Modernization/GNSS Plans for civil use**
  - Today, Full GPS constellation (29 actively transmitting Jan 2007) with L1 civilian broadcast signal
  - GPS Modernization plan
    - Block II-F (2007), Block III (2012) adds L5 (aeronautical use)
    - L1, L2C, L5 available IOC in 2012 and FOC by 2015
  - Identify other GNSS Modernization Plans
    - GLONASS - 11 (Feb 2007) with goal of 24 satellites by 2010
    - Galileo - 30 launches between 2006 – 2010 with L1, E5
- **GNSS Benefits to air navigation:**
  - Dual frequency avionics can develop self-generated onboard ionospheric corrections
  - Integrity and ionospheric correction data for L1, E5/L5 to be available from SBAS, GBAS
  - Provides aviation with continuous, highly accurate, 3-D position information
  - L1 + L5 + SBAS: Potential precision approach capability, Cat I operations
  - L1 + L5/E5 + GBAS: Expected to ultimately support Cat II / III operations

Future Operational Environment – GPS/GNSS



- **Avionics using modernized GNSS**
  - Improved accuracy, integrity, availability, and continuity
  - Receiver Autonomous Integrity Monitoring (RAIM)
  - Dual frequency (L1 and L5) avionics can develop self-generated onboard ionospheric corrections
- **Define Needs Based on SATNAV Vulnerabilities**
  - Vulnerabilities of SATNAV
    - Atmospheric anomalies
    - Unintentional or intentional interference
    - Military testing
    - Potential system failure
      - Space segment, Ground segment, SBAS / GBAS
  - We note that GPS has had an excellent system reliability record
  - Independent GNSS (GPS + GLONASS + Galileo) systems eliminate common points of failure
  - Spectral diversity (L1 + L5) helps mitigate the problem from unintentional interference
    - Expect NPA capability could be maintained with disruption to one signal component
  - Interoperability requires systems to share a few common frequencies
- **Summary Points**
  - GPS modernization and global additions to GNSS benefits aviation:
    - Spectral diversity improves accuracy and reduces vulnerability to unintentional interference
    - More valuable asset that better meets the needs of satellite based navigation
  - However, satellite based navigation remains vulnerable to intentional interference
    - systems share a few common frequencies at very low power levels
  - This, with national policy, motivates and directs the need for SatNav backup

Identify Capabilities – FAA Roadmap for Performance Based Navigation



Near Term (2006-2010)	Mid Term (2011-2015)	Far Term (2016-2025)
En Route ❑ RNAV Q routes ❑ RNP-2 routes ❑ T routes and lower MEAs ❑ Requirements to incorporate aircraft navigation capabilities into en route automation **Oceanic** ❑ RNP-10 and 50/50 NM lat/long Pacific ❑ RNP-10 and 60 NM lat in WATRS ❑ Expand 30 NM longitudinal/ 30 NM lateral separation (30/30) in the Pacific ❑ Explore RNP-4 in NAT **Terminal** ❑ RNAV SIDs/STARs at OEP airports ❑ RNP-1 SIDs/STARs where beneficial ❑ Automation requirements for merging RNAV arrivals ❑ Concepts for RNAV and RNP with 3D, constant descent arrivals (CDA), and time of arrival control **Approach** ❑ At least 25 RNP SAAAR per year ❑ 300 RNAV (GPS) per year ❑ Standards for closely spaced and converging runway operations based on RNP	**En Route** ❑ RNP-2 routes ❑ T routes and lower MEAs ❑ Enhanced automation incorporating aircraft navigation capabilities ❑ At end of mid term, mandate RNP-2 at and above FL290, and mandate RNAV at and above FL180 **Oceanic** ❑ Limited RNP-4 and 30 NM lat in WATRS ❑ Increase use of operator-preferred routes and dynamic re-routes **Terminal** ❑ RNAV SIDs/STARs at many of the top 100 airports ❑ RNP-1 or lower SIDs/STARs where beneficial ❑ Airspace redesign and procedures for RNAV and RNP with 3D, CDA, and time of arrival control ❑ At the end of mid term, mandate RNAV for arriving/departing at OEP Airports **Approach** ❑ At least 50 RNP per year ❑ 300 RNAV (GPS) per year ❑ Closely spaced parallel and converging runway operations based on RNP ❑ Satellite-based low visibility landing and takeoff procedures (GLS)	**Performance-Based NAS Operations** ❑ RNP Airspace at and above FL290 ❑ Separation assurance through combination of ground and airborne capabilities ❑ Strategic and tactical flow management through system-wide integrated ground and airborne information system ❑ System flexibility and responsiveness through flexible routing and distributed decision-making ❑ Optimized operations through integrated flight planning, automation and surface management capabilities ❑ Mandate RNAV everywhere in CONUS ❑ Mandate RNP in busy en route and terminal airspace

Requirements for Satellite Navigation Backup

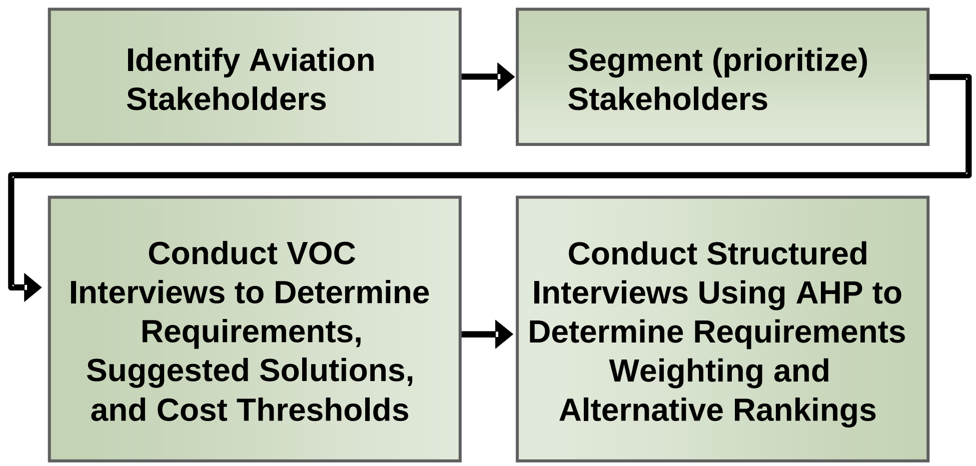
- Navigation Technical Performance Requirements
  - Minimum technical requirements (***accuracy, integrity, availability, continuity, coverage)***
    - En route ≤ RNAV RNP 2.0
    - Terminal ≤ RNAV RNP 1.0
    - Non Precision Approach (NPA) RNAV RNP 0.3
  - Support for precision approach LPV, CAT I, CAT II/III
  - Support for surface navigation
- Functional Requirements
  - Seamless transition or backup procedures invoked
    - ATC and flight crew
  - Support navigation for a terminal area GNSS disruption
    - Provide navigation support from en route to the approach
  - Technical readiness within 2015-2025
    - Technology, standardization, avionics, certification
  - Global support (goal)
- Life Cycle Cost
  - Infrastructure
  - Users

Aviation Stakeholders

- Air Carrier
  - International
  - Domestic (CONUS, Europe)
  - Regional
  - Freight Carrier
- General Aviation
  - Air Taxi
  - Business
  - Other
- Military
- Airframe builders
- Avionics manufacturers
- Government / regulatory / standards groups

Subtask: Stakeholder Interview Segments

- Round 1
  - Determine Stakeholder suggestive backup alternatives
  - Determine system requirements, cost thresholds
  - Derive the Decision Factors
- Round 2
  - Conduct structured Interviews using Analytical Hierarchy Process (AHP)



Subtask 5 Flow Diagram

Aviation Stakeholder voices

Air Carrier

- International
  - Values Interoperability and common standards
  - Would like common backup for US / Europe
  - Long equipage cycles ~ 25 years
  - See DME/DME/INS and ILS as backup.
- Domestic (CONUS, Europe)
  - Backup should provide same level of performance as the prime.
- Regional
  - More likely to fly smaller airports, feeding hubs. More flights into less equipped airports (w/ lower DME/DME coverage). Will use GPS/WAAS as primary.
- Freight Carrier
  - Traffic sequencing clumped. Cost issue on efficient air sequencing and efficient traffic flow.

Air Carrier Stakeholder Comments

- *“Would not like there to be multiple systems required e.g. one backup in the US and one in Europe. Prefer to have a globally harmonized backup system.”*
- *“In the North Atlantic it is intended to go to 30/30 separation, which would not be possible without GPS. Consequences (of an outage) would be larger separations with a concomitant reduction in capacity/efficiency.”*
- *“DME is good as aircraft already have the necessary equipment so there is no additional cost.”*

Aviation Stakeholder voices(2)

General Aviation

- Business
  - Likely equipage (DME/ILS/VOR). Some larger ones may have INS. Equipage for lower altitude, may use VOR for traditional route structure.
- Air Taxi
  - Will fly RNAV RNP. Very flexible, book seat when you need it to where you want to go.
  - Values potential of satellite navigation for precision approaches
- Other
  - Cost sensitive. May not add backup capability.

General Aviation Stakeholder Comments

- *"There is high GPS usage among all members with approximately 70% of them using GPS as their primary NAV source."*
- *"We see increased reliance on GNSS as it continues to evolve."*
- *"For GA, the first hour is the critical period and it may be that once aircraft are on the ground they will be kept on the ground until the service is resumed."*
- *"Our concern is what happens when the pilots that currently use moving maps for situational awareness and those that use electronic charts no longer have such technology if the system goes down. This could create safety of flight, security and terrain avoidance issues if those pilots, GA or other, are not familiar with old technology and how to quickly transition to using that old technology on a real-time basis."*
- *"Any backup should be available and meet all operational requirements of users. Low price aircraft should not be limited by any requirements of a backup system. Small aircraft cannot install INS systems."*

Aviation Stakeholder voices(3)

Military
- Large number of ground aids unique to the military- TACAN, DMER
- No policy for civil use of DoD owned TACAN and DME facilities

Airframe builders
- *"GPS and hopefully one day Galileo is probably the best navigational aid ever seen. It is very useful, and there is an increasing reliance upon it."*
- *".. to position aircraft across track e.g. for RNP of 0.3 or lower, GPS is the only practical way of positioning the aircraft."*
- *"The geometry of DMEs is almost never appropriate for RNP-0.3."*

Avionics manufacturers
- Needs standards to develop avionics.
- Cost, size, weight are important.

Avionics manufacturer Stakeholder comment
- *"It is prudent not to put all eggs in one basket. We should maintain a skeleton backup network to address any concerns."*
- *"The future system design should, due to performance requirements, cover such issues as short term outages (of GPS)."*
- *"DME- The problem is, achieving full coverage; there would have to be an increase in the number of DMEs and there would be a corresponding increase in frequency congestion."*

Aviation Stakeholder voices(4)

Government / regulatory / standards group comments

- *"GPS alone is not acceptable as the sole navigation aid - the weakness of the signal, single channel and common mode failure risks all have .. implications."*
- *"Any backup system must meet the same standards of service as the system it is replacing. If backup system cannot do this, it must be stated what level of service can be provided."*
- *"They should ensure a similar level of performance. Cost and safety are essential for decision."*
- *"DME incurs very high costs to use the spectrum."*

European Views

- *"GNSS CAT1 level will be achieved by the middle of the next decade. ILS to be maintained for the foreseeable future because of cost effectiveness."*
- *"The European navigation plan shows that the DME-DME infrastructure will be maintained for some time to come."*
- *"In ECAC region a acceptable backup to SATNAV is required and this will be DME."*
- *"LORAN may give better coverage but its introduction into Europe would require the entire auxiliary element to be developed – procedures, rules, charts, publications (in addition to the equipment fit)."*

SatNav Backup Candidate List	Flight Operational Phase		
	En Route, Terminal, NPA	Precision Approach	Surface
DME/DME/INS	Candidate		With surface point update to INS
eLORAN	Candidate	Candidate LPV w / barometric	With differential augmentation
GPS / Inertial	Candidate	Candidate LPV w / barometric	With surface point update to INS
VOR Minimum Operational Network	Candidate		
Hardened GNSS receiver	Candidate	Candidate	Candidate
Terrain Reference Navigation	Candidate		Candidate
Multilateration w/ A/G comm data link	Candidate		Candidate
ILS (localizer + glide slope indicator)		LPV, CAT I / II / III Candidate	
Hybrid: glide slope indicator + eLORAN		LPV Candidate	
Embedded surface markers for guidance			Candidate

Components of this Study

- Systems Engineering and Analysis
  - Technical Requirements
  - Functional Requirements
  - Life Cycle Cost
- 'Voice of the Customer' Stakeholder content
  - Round 1 Stakeholder Interviews
    - Identify Requirements
    - Identify Candidates
  - Round 2 Stakeholder Interviews
    - Analytic Hierarchy Process
      - Relative weighting of decision factors
      - Determine SatNav Backup recommendations

You are invited to add your opinions as an aviation stakeholder.