National Aeronautics and Space Administration

ICNS 2019

CNS Simulation Tool Development for Increasingly Complex Airspace Operation Evaluation

Rafael Apaza, Michael Marsden
NASA Glenn Research Center, Cleveland, Ohio

April 11, 2019

Rafael.Apaza@NASA.gov
Michael.Marsden@ NASA.gov

Presentation Outline

1. Introduction
2. SMART NAS Testbed Background
3. SMART NAS Testbed Architecture
4. CNS Model Development & Design
5. Evaluation Results
6. Conclusion

Introduction

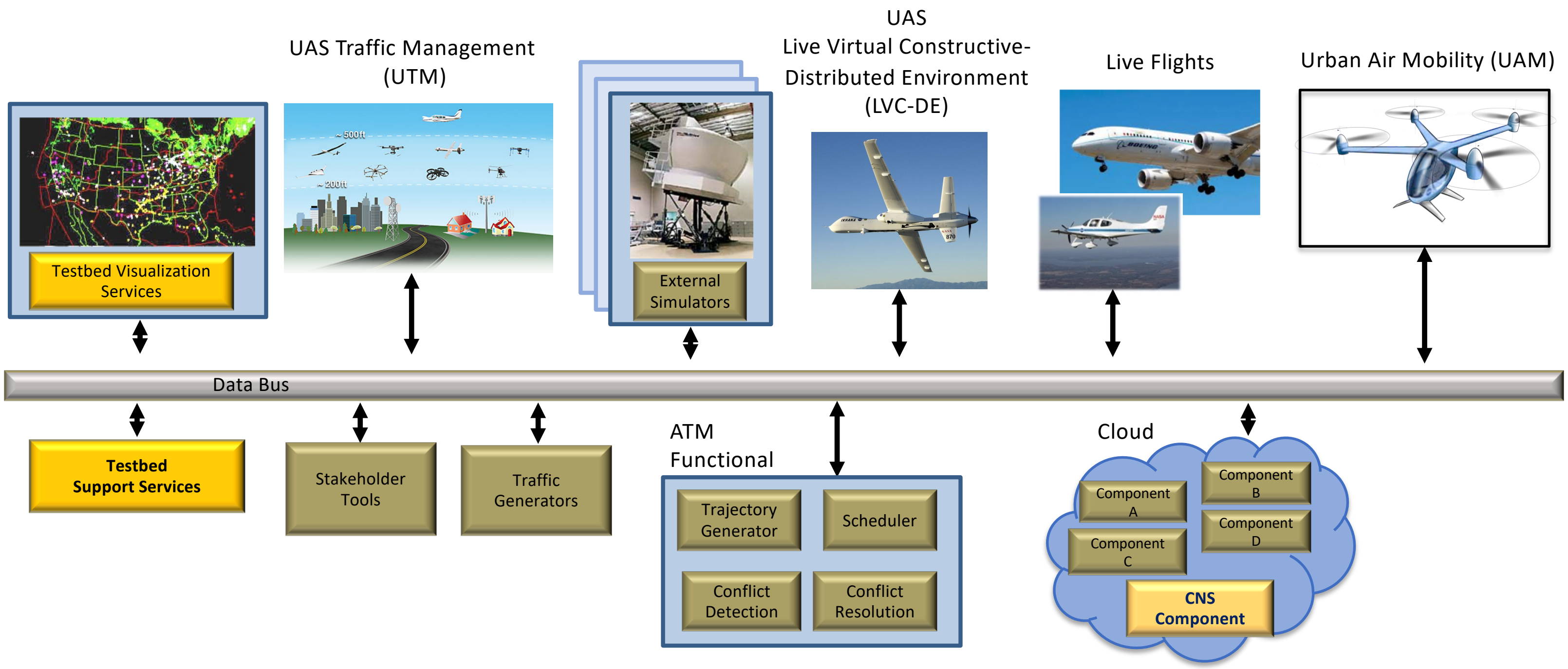
- NASA Shadow Mode Assessment using Realistic Technologies for the National Airspace System (SMART NAS) initiated Test Bed Development
- Under the Air Traffic Management eXploration (ATM-X) Project, NASA is continuing testbed modernization and expanded development of new simulation tools and capabilities to include operations for new airspace users
  - Evaluation of new Air Traffic concepts, technologies and vehicles with new missions seeking entry into the airspace requires the use of simulation capabilities not currently available
- Purpose is to conduct high-fidelity, real-time, human-in-the-loop and automation-in-the-loop simulations
- This presentation describes CNS simulation architecture and software design developmental efforts

CNS Simulation Background

- NAS depends on CNS systems to deliver ATM services and these technologies have performance and reliability limitations
- Modern and vintage CNS technologies used today e.g. VOR-DME, GPS
- CNS simulation is required for optimal system architecture design, risk mitigation, operational efficiency, service degradation evaluation, and more.
- CNS modeling provides scalability analysis, efficiency performance, realistic assessment and assist in proof of ATM Concepts
- NASA Glenn Research Center is developing CNS tools to evaluate existing and future ATM concepts that considers existing and new vehicle operations.

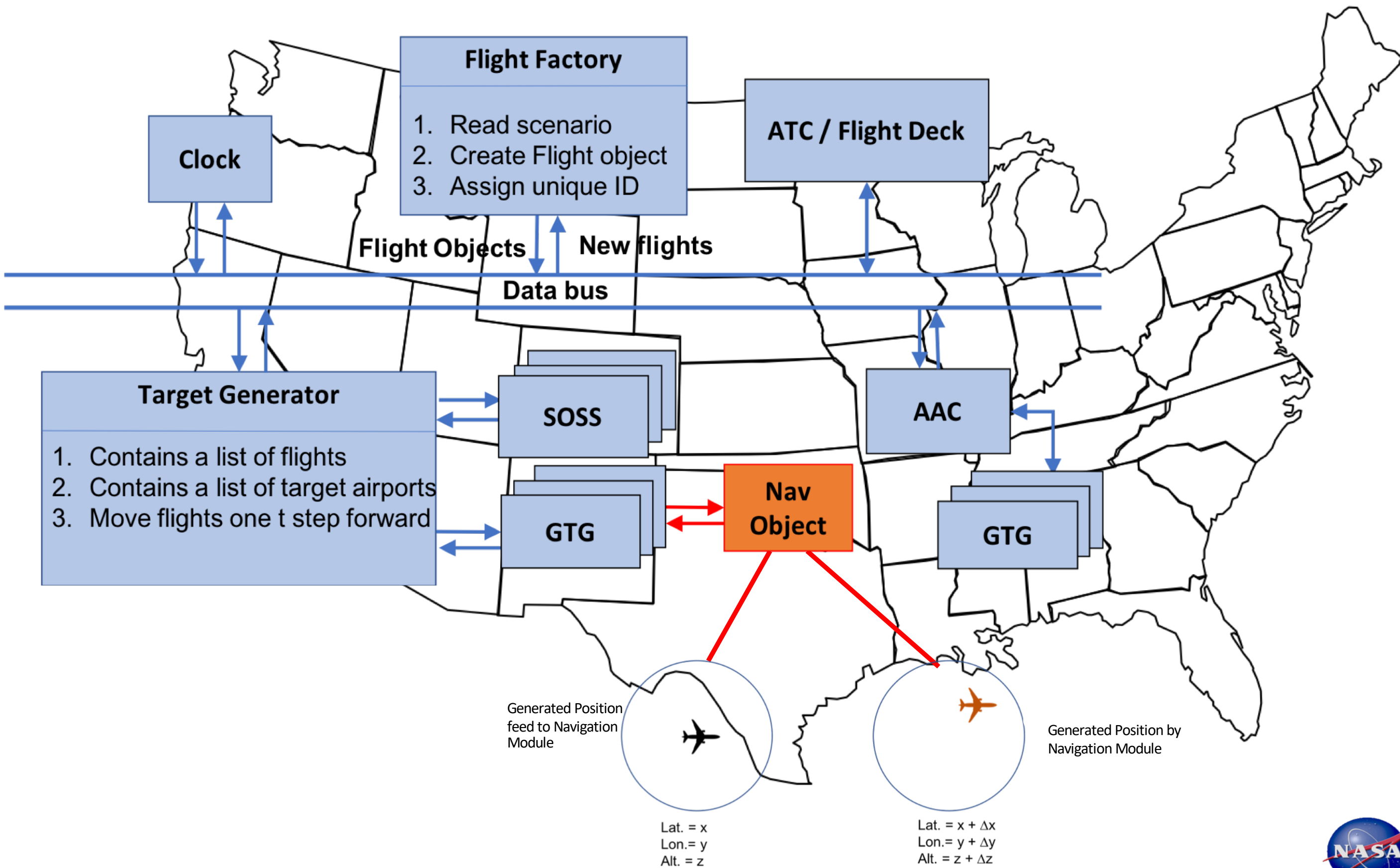
National Aeronautics and Space Administration

Testbed Architectural Elements



CNS Model Development

- Navigation Module designed as a submodule of Target Generator
- Navigation Module adds uncertainty to the track
- Provides adjustable parameters for aircraft position variability
- Provides position generation using statistical approximations



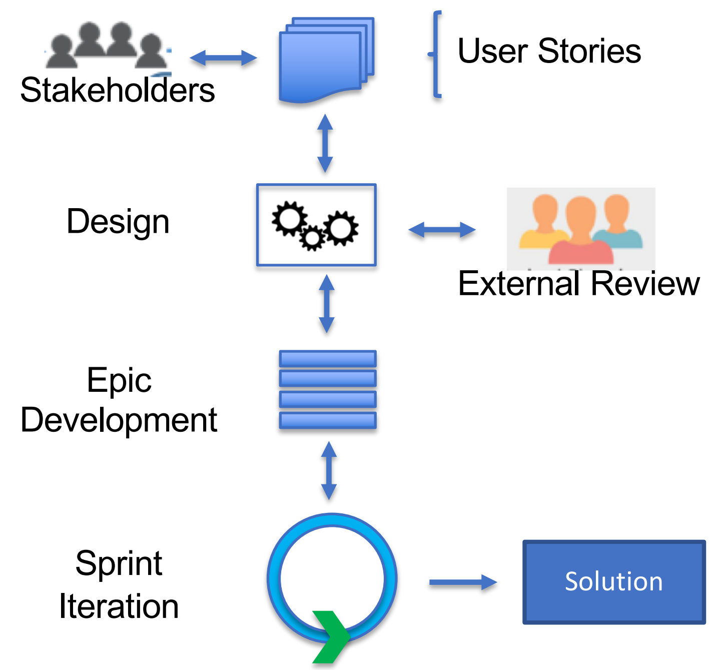
CNS Model Development

- Development code written in the programming language of Java, using OpenJDK 11.
- Coding standards based on SMART NAS Testbed's (SNTB) Java coding standards.
- Atlassian collaboration products employed such as Jira®, Confluence®, Bitbucket®, and FishEye®.
- *Agile* style approach for software development and project management.

Software Engineering Development

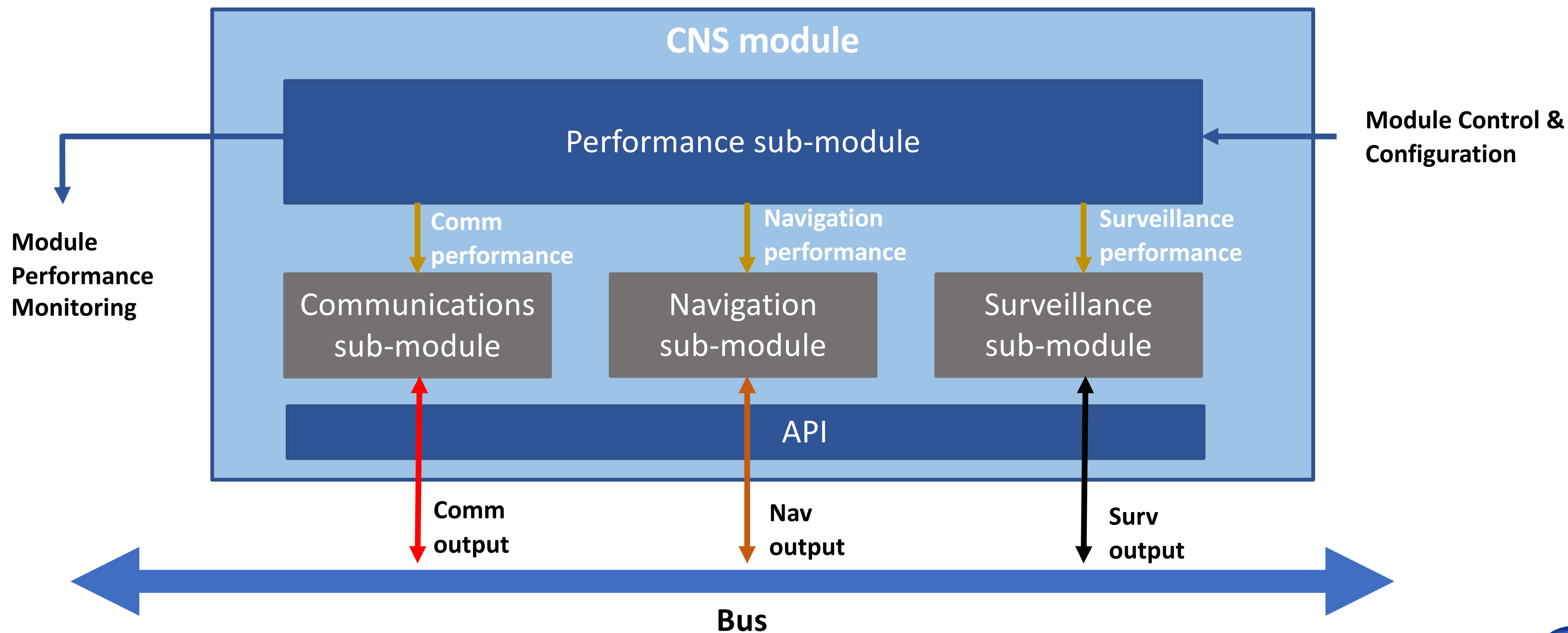
Agile Approach for Testbed Development

- User stories development & priority assignment
- User story implementation design
- External Review
- User story task decomposition into tasks – Epic assignment
- Sprint Iteration – coding/testing
- Demonstration to Stakeholders
- Release solution into production



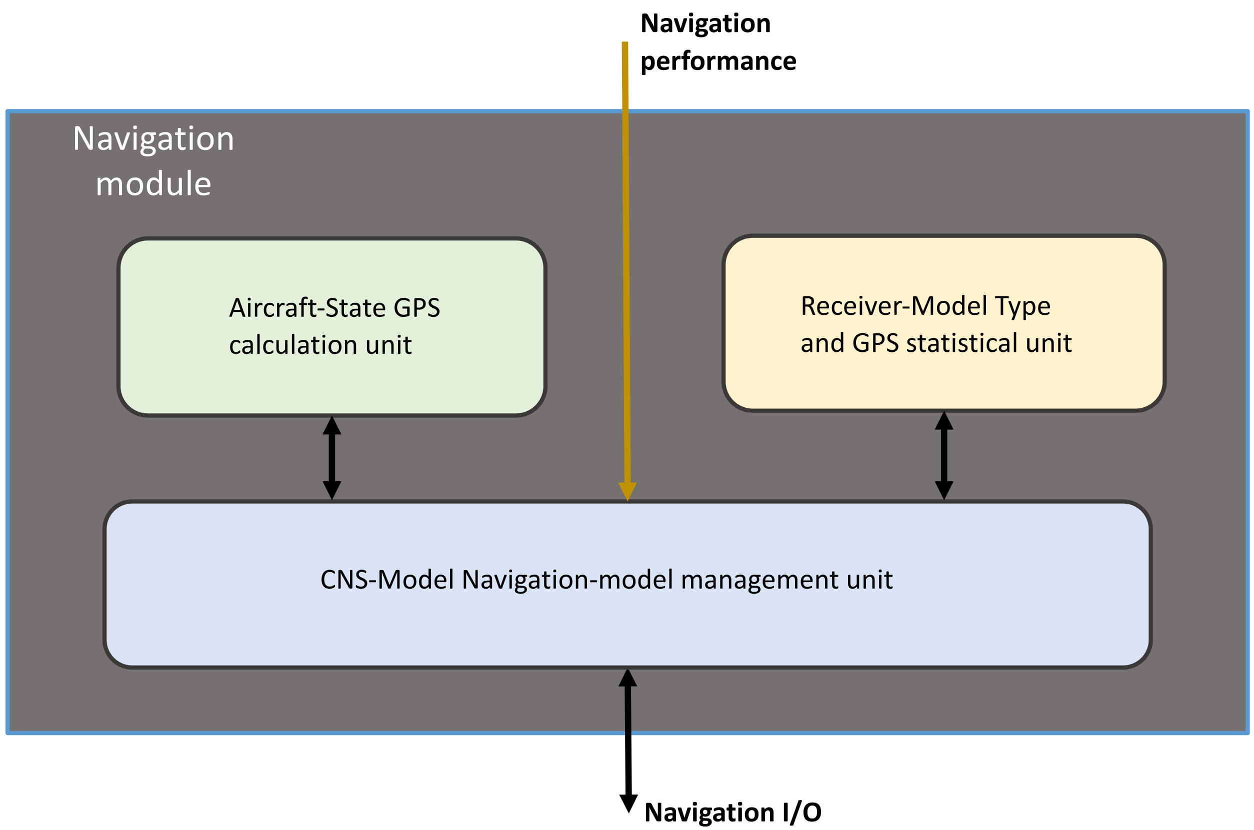
CNS Module Architecture

High level notional CNS module



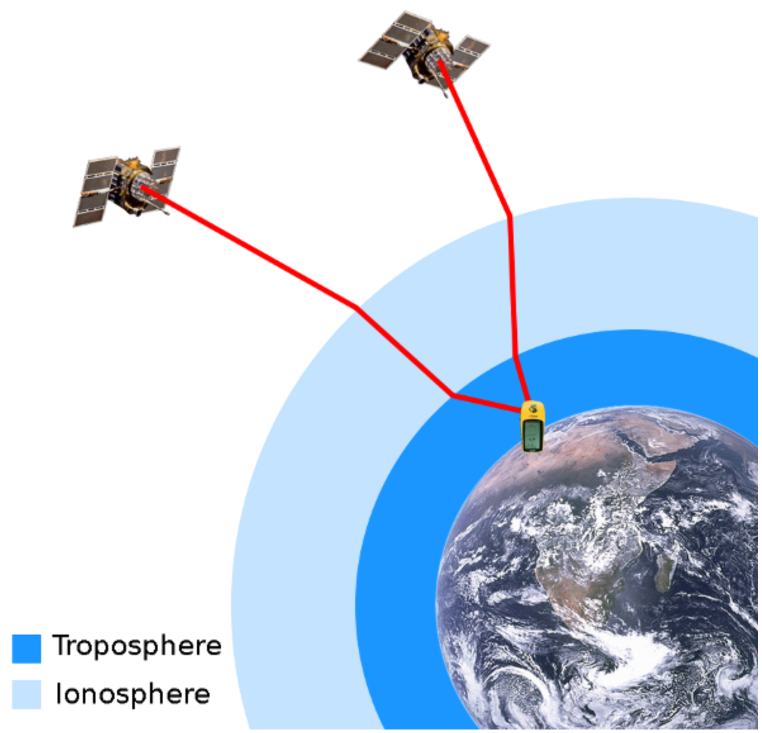
Navigation Module Architecture

- **Management Unit** – Controls *request* and *response* between the TG and Nav Object, as well as data exchange between internal units.
- **GPS Calculation Unit** – Holds the current state of the aircraft and calculates the GPS position with applied error based on the input (x, y, z) and GPS errors from the GPS Statistical Unit.
- **GPS Statistical Unit** – Holds the values for inherent GPS errors and a ReceiverType.

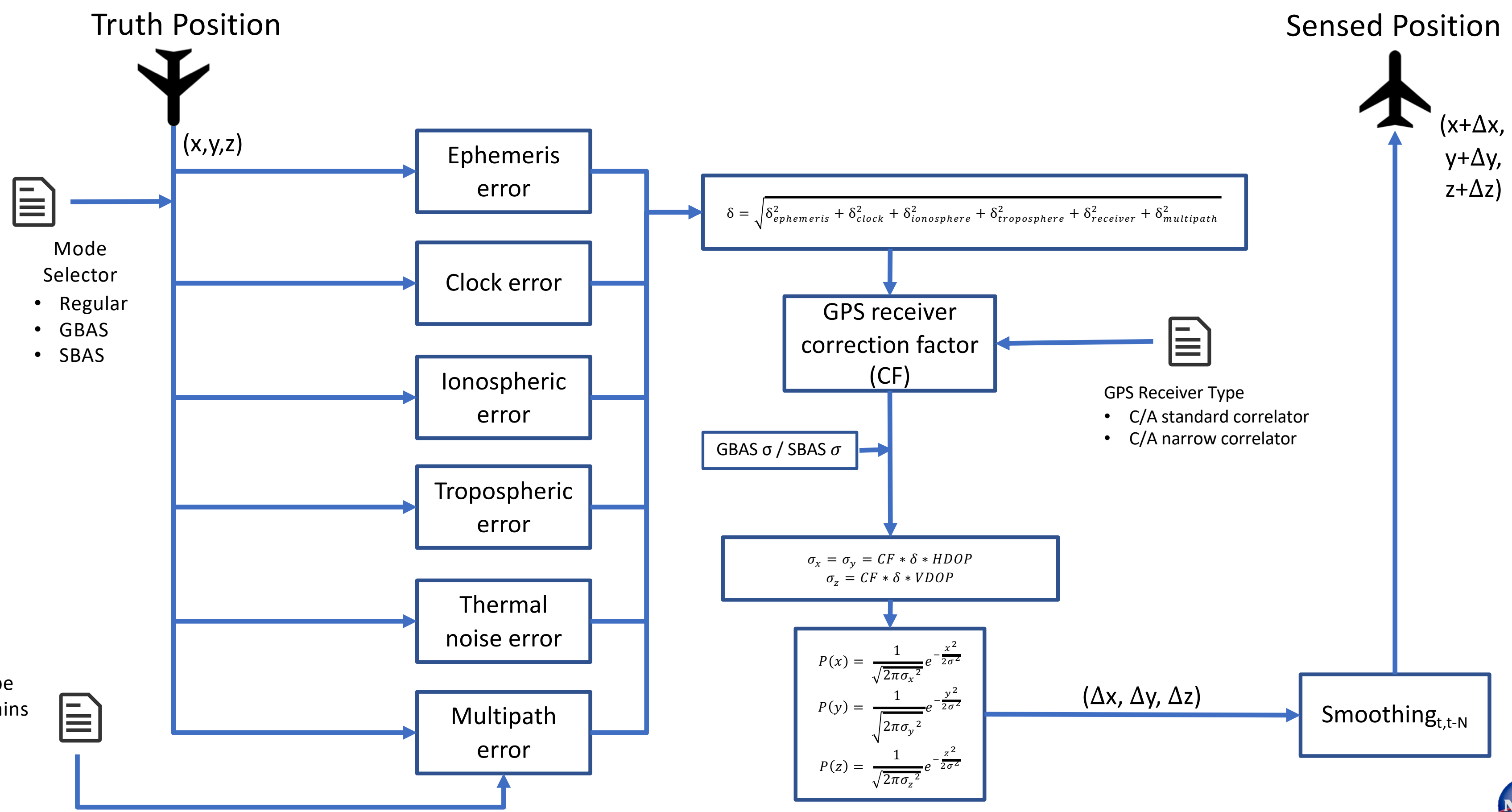


Model Design Error Considerations

- **Ephemeris** - Errors in the transmitted location of the satellite.
- **Clock** - Residual errors from clock drift and noise in the transmitted clock.
- **Ionospheric** - Errors caused by the signal transmission through the Ionosphere.
- **Tropospheric** - Errors caused by the signal transmission through the Troposphere.
- **Thermal noise** – Errors caused by the receiver's thermal noise.
- **Multipath** - Errors caused by reflected signals entering the receiver antenna.

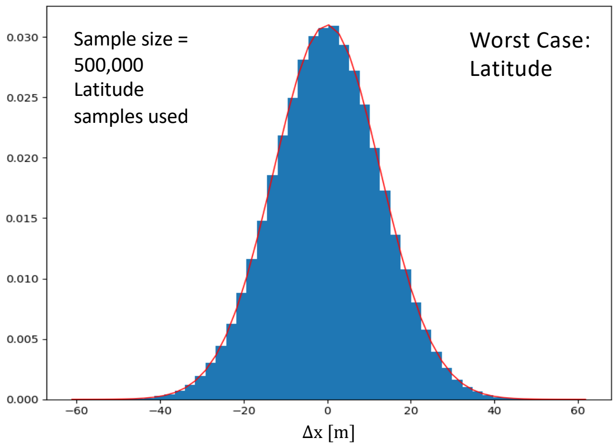


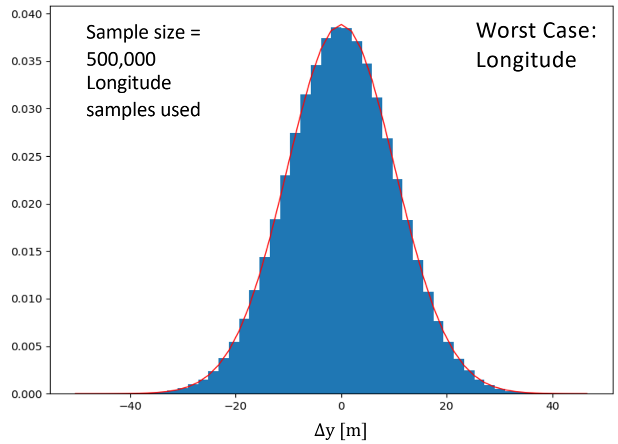
Module Design – Position Determination



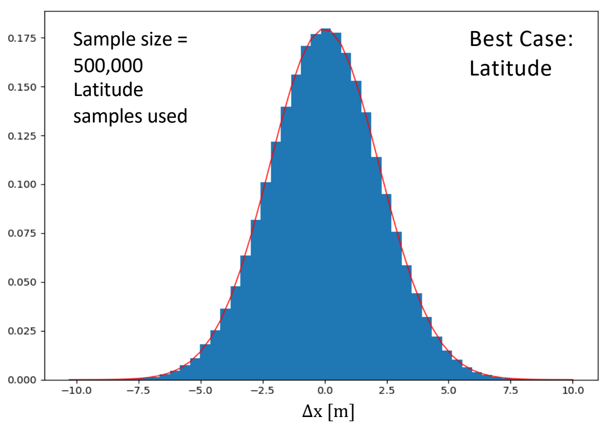
Navigation Module Evaluation

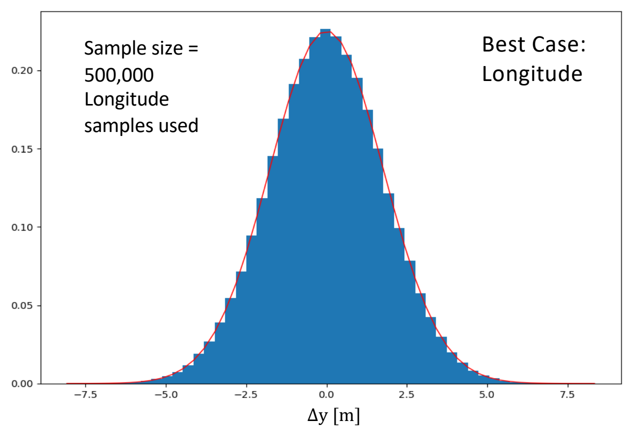
GPS error applied to the true position





Max Latitude Error:	87.0558	meters
Max Longitude Error:	67.2873	meters
Max Altitude Error:	133.6660	meters
Min Latitude Error:	-71.3894	meters
Min Longitude Error:	-67.0877	meters
Min Altitude Error:	-108.8807	meters
Mean Latitude Error:	-0.0172	meters
Mean Longitude Error:	0.0028	meters
Mean Altitude Error:	0.0066	meters
StdDev Latitude Error:	12.8611	meters
StdDev Longitude Error:	10.2665	meters
StdDev Altitude Error:	13.6646	meters

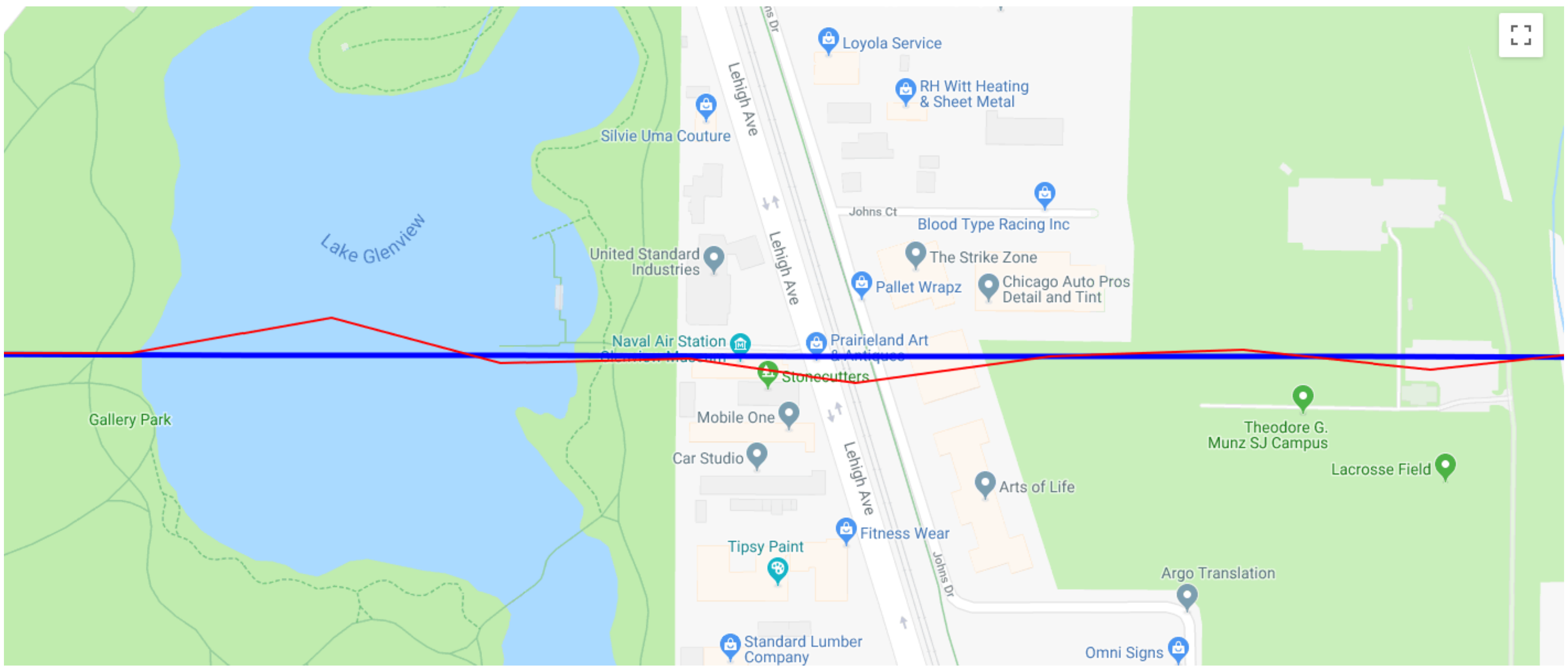




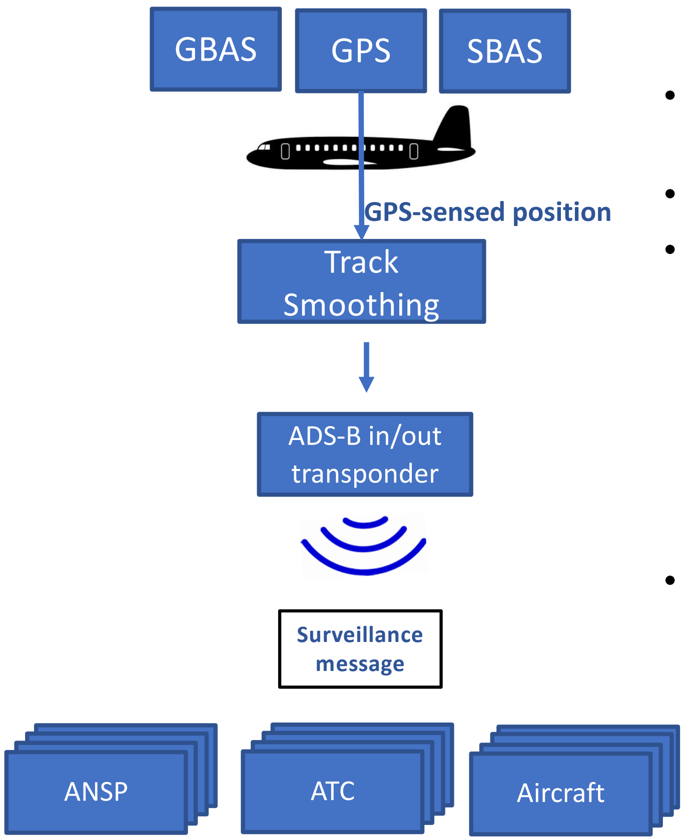
Max Latitude Error:	11.7612	meters
Max Longitude Error:	9.2523	meters
Max Altitude Error:	18.1641	meters
Min Latitude Error:	-11.2876	meters
Min Longitude Error:	-9.7336	meters
Min Altitude Error:	-16.8812	meters
Mean Latitude Error:	-0.0019	meters
Mean Longitude Error:	-0.0003	meters
Mean Altitude Error:	0.0037	meters
StdDev Latitude Error:	2.2216	meters
StdDev Longitude Error:	1.7719	meters
StdDev Altitude Error:	2.3669	meters

Navigation Module Evaluation

KML overview with Blue = Truth_Position, Red = Sensed_Position



Next Phases



- Implement satellite based augmentation and ground based augmentation
- Develop and implement Track Smoothing capability
- Implement air-ground ADS-B Out/In
  - Transmits GPS position calculated by basic airborne sensed position module
  - Non-ideal availability, latency and message drop
  - Statistical distance between aircraft and ground station
  - Independent to the realistic characterization of GPS accuracy in basic module
- Development of air-ground surveillance modules
  - Cooperative radar (SSR – PSR + Mode-S)
  - Airport Surface Detection (ASDE)

Conclusions

- A new suit of tools are required to evaluate future concepts of operations and meet the fast evolving demand for new vehicle entries and their operations in the NAS
- Under the SMART NAS project, NASA started the effort to develop state of the art capabilities to meet new challenges and demands for expediting complex concept evaluation.
- A simulation environment that evaluates complex operations in a realistic environment needs to be user friendly, interoperable with existing and new tools, modular, have adequate fidelity, security, scalability and cost effective.
- NASA Glenn Research Center is developing new and improved CNS simulation tools for a realistic evaluation of ATM concepts for existing and new vehicle operations.