SPECTRUM PIPELINE REQUEST 1675 – 1680 MHZ ENGINEERING STUDY (SPRES) PROGRAM

National Academies of Sciences - Engineering – Medicine

COMMITTEE ON RADIO FREQUENCIES

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Overall Scope

The Spectrum Pipeline Reallocation Engineering Study (SPRES) assesses the potential for sharing the 1675-1680 MHz frequency band and the adjacent frequency bands with commercial mobile wireless carriers, nationwide.

- Establish a user/customer data flow and user needs baseline to facilitate quantifying impacts to end users resulting from a loss of access to data received via direct broadcast links
  - Identify options to mitigate interference – occurrences and impacts
- Perform interference analysis to determine Interference Protection Criteria (IPC) for federal Earth stations and protection zones around these downlink sites
- Examine Radio Frequency Interference (RFI) monitoring and other mitigation techniques
- Examine alternative architectures for future implementation on space and ground based assets, i.e., GOES-Next

Technical Concept, Justification, and Impact

- **Technical Concept:** The study will be done using engineering analysis including models, simulations, and field testing.

- **Justification**: To increase the possibility of a successful spectrum auction for the 1675 – 1680 MHz Frequency. Congress provided funds to study the impacts from sharing, possible mitigations, alternatives and recommendations to facilitate spectrum sharing in the band.

SPRES Program

11 projects to meet the goals of the engineering study

- **1 – Spacecraft-to-end user data flow analysis**
- **2 – Analysis of impacts to users**
- **3 – Alternative GOES ground system architectures**
- 4 – ROM costs for implementing alternative architectures
- 5 – Alternative communication techniques for satellite downlinks
- **6 – Detailed survey of receiving equipment**
- 7 – Protection studies
- **8 – Anomalous propagation interference to critical GOES stations**
- **9 – Interference thresholds for federal GOES-R broadcast receivers**
- **10 – RFI monitoring analysis for the 1675-1680 MHz band**
- **11 – LTE TDD simulations, passive site surveys, and active test**

The program Critical Path goes through Projects 1, 3, and 4

Blue = project completed
Tan = project in progress

Each project has its own end result. Some are more interdependent than others.

Results to Date

Project 1 – Spacecraft-to-end user data flow analysis

- The major results of Project 1 include a quantification of the numbers of, and descriptions of, receive sites and users of NOAA GOES information services
- This project discovered multiple GOES data services, served by this band, that are employed by federal and non-federal users
- It also uncovered a wide variety of developed applications across multiple economic sectors, which have varying tolerances for data latency and loss, and quantifiable impacts when data is delayed or lost.
- This project identified a large number of non-federal users with varying data requirements using 1675 -1680 MHz band.

A range of data applications and end users connected to the 1675-1680 MHz band were found, often with complex interconnections.

Results to Date *(2 of 5)*

Project 2 – Analysis of impacts to users

- Project 2 provided a more detailed look at GOES signals and configurations, a qualitative Radio Frequency Interference (RFI) susceptibility analysis, and potential impacts to users and applications for 37 Federal GOES sites. The susceptibility analysis included general site configuration and environmental factors, two LTE deployment models, and both ITU and measured receiver interference thresholds.
  - Analysis did not include the potential risk due to anomalous propagation, ground clutter effects, or the beneficial impact of mitigations
  - Sites were rated high, medium or low for RFI risk
- This project found that the primary risk of interference in either the 1675-1680 or 1680-1695 MHz bands is from AWS downlinks due to downlink transmitters with higher EIRP and antennas that are located high above the terrain
- Twenty-two sites were classified high risk because they are unable to achieve a high enough frequency dependent rejection (FDR) to mitigate the potential of interference

Each site's susceptibility to local FDD LTE was assessed - before any mitigation was applied or anomalous propagation considered.

Results to Date *(3 of 5)*

Project 8 – Anomalous propagation interference to critical GOES stations

- Project 8 modeled Anomalous Propagation of AWS signal energy due to atmospheric ducting
- The project found that several sites, primary located along the Atlantic and Gulf coasts, have statistically significant probabilities of strong ducting events
- Overall findings show that such ducting can have a significant impact on RFI risks. In non-ducting conditions, protection zones of 50 km to 100 km are sufficient. However, under strong ducting conditions a greater than 5% risk of aggregate RFI risks exists, even with exclusion distances exceeding 500 km. The level of risk varies according to the ducts' spatial size, strength, LTE tower density, and terrain effects.
- Static protection zones required to reduce RFI risks to less than 5% will be large and encompass many heavily populated areas. Some form of adaptive sharing such as a dynamic exclusion technique may be required.
- The study also investigated the ability to detect the onset of anomalous propagation and selectively mitigate RFI. Anomalous propagation detection may be possible by monitoring for RF signal amplitude changes in the local region.

AP caused by ducting can be a significant contributor to in-band RFI risk at some locations. Site specific impacts for at-risk sites will be assessed in project 7 and depend upon specific GOES signals used. Mitigation options based on detection or prediction and adaptive coordination will require additional study.

Results to Date *(4 of 5)*

Project 9 – Interference thresholds for federal GOES-R broadcast receivers

- Project 9 determined interference thresholds above which federal GOES-R satellite broadcast receivers will suffer degraded or lost data, and evaluated the spectrum sharing benefits and limitations of decoding the AWS transmitter Carrier ID (CID) to assist with RFI mitigation
  - RFI threshold measurements were conducted and results obtained for the DRGS/DCPR, GRB, and HRIT/EMWIN signals from the GOES-R Series satellite
- The primary concern is the risk for RFI to the DRGS/DCPR downlinks due to partial overlap with the 1675-1680 MHz band. The DRGS system and signal design increase its susceptibility to interference. The GRB signal is somewhat less susceptible to interference due to a constant operating power (minimum is end-of-life power) and a robust signal encoding
- The most significant benefit to spectrum sharing of CID information is that decoding of the CID was demonstrated to work effectively in the presence of individual received signals. However, if there are multiple signals present, only the strongest signal will be decoded.
  - A likely RFI scenario is multiple signals with similar power levels where CIDs can not be decoded

The DCS DCPR signal is the most vulnerable to interference. Carrier ID does not appear to be useful as a mitigation tool in most interference scenarios.

Results to Date *(5 of 5)*

Project 11 – LTE TDD simulations, passive site surveys, and active test

- Project 11 used modeling to assess whether LTE TDD presented a different or increased RFI risk to GOES receivers relative to LTE FDD
  - TDD LTE combines uplink and downlink traffic on the same frequency channel, separating these modes of operation using time slots
  - Propagation modeling using standard models similar to CSMAC modeling for AWS-3 and various TDD configurations was used
- The result was that RFI was dominated by FDD downlink factors and TDD cases presented no additional RFI risks.

FDD downlink operation is the dominant mode for LTE RFI analysis, and can also be used to represent RFI analysis for TDD operations.

In-Process

Project 6 – Detailed survey of receiving equipment

- Project 6 will provide details of federal earth station GOES satellite broadcast receiver susceptibility to RFI, based on on-site assessments of a representative group of sites. It will also accomplish mapping of data distribution architectures both from satellite to ground, and from collection to end users, to define commercial and national relationships.
- It will build on Project 2 results.
- This project is more than one-half complete with 25 of 35 sites surveyed. It has yielded important data regarding local signal propagation, local background noise levels, and site specific configuration and data architecture, including already implemented alternatives (backups) to direct broadcast reception.

Project 6 will provide a detailed look at site GOES configuration, data architecture, and data flows.

In-Process *(2 of 3)*

Project 3 – Alternative GOES ground system architectures

- Develops a detailed description of viable alternatives for legacy GOES and GOES-16+
  - ➢ Dependent on Project 1 outputs (completed)
- Four alternative dissemination architectures for DCS & GRB have been identified and are being scored against multiple criteria, including data latency and technical risk.

Project 3 will identify and score alternative dissemination methods as a potential mitigation to direct broadcast data loss.

In-Process *(3 of 3)*

Project 10 – RFI monitoring analysis for the 1675-1680 MHz band

- Perform trade study on the state of current and future monitoring capabilities
  - ➢ Dependent on Project 6 outputs (incrementally)
- Work performed on the project is in initial phases

Project 10 will assess the potential for Carrier ID to mitigate carrier based RFI, and will look more broadly at radio frequency interference monitoring capabilities.

Expected Outcomes

With Dependencies (prerequisites)

Project 4 – ROM costs for implementing alternative architectures provided in Project 3

- Cost and schedule for design, development, and implementation of alternative architectures to current dissemination methods
  - ➢ Dependent on Project 3 (completed) outputs

Project 5 – Alternative communication techniques for satellite downlinks

- Latency and availability information of downlink data in alternative architectures
- Recommendations for GOES-Next bandwidth and modulation requirements
  - ➢ Dependent on Project 3 (completed) outputs

These projects will provide ROM costs for alternate dissemination architectures as well as the viability analysis of alternative dissemination methods as a potential mitigation. Future broadcast architectures are assessed for viability.

Expected Outcomes *(2 of 2)*

With Dependencies (prerequisites)

Project 7 – Protection Studies

- Quantify impacts from in-band and adjacent-band LTE and other RFI sources
- Definitive protection criteria and protection zones
  - ➢ Dependent on Project 6, 9, and 11 (incrementally) outputs

The results of the other projects will be integrated in this project, capturing contributions from all RFI sources, site specific design and requirements, calculating protection zones, and proposing mitigations to determine sharing viability.

Implementation: Acquisition Strategy

Aerospace Corporation:
Contract # SP-133E-17-CQ-0020, Task Order 12
Program Support
POP: 1/1/2017 - 11/31/2020
Total: $2,346,269.00
Base period $782,818.00

Freedom Technologies Incorporated
Contract # SP-133E-18-CQ-0015
IDIQ Awardee
POP 2/6/2018 - 2/5/2020
Total NTE $8,000,000
Award $10,000.00

Next Phase Solutions and Services, Inc.
Contract # SP-133E-18-CQ-0017
IDIQ Awardee, Projects 1, 2 & 9
POP: 2/1/2018 - 1/31/2020
Total: NTE $8,000,000
Award $1,132,857

Shared Spectrum Company
Contract # SP-133E-18-CQ-0016
IDIQ Awardee, Projects 6 & 8
POP 2/1/2018 - 1/31/2020
Total NTE $8,000,000
Award $2,751,825

Contract Schedules & Status

Task Order	Description	Awardee	Planned Award Date	Actual Award Date	Duration/ POP (Months)	1/3 Complete Report	2/3 Complete Report	Final Report Completed/due	Status
Program Support - Task Order 12	Provide engineering and program management support to manage execution of projects	Aerospace Corporation	N/A	1/1/2017	01/31/2018 - 2/28/2020	N/A	N/A	January, 2020	On-track
Project 1	Map Spacecraft and End User data flows and document user needs	Next Phase Solutions and Services, Inc.	1/31/2018	2/22/2018	11	4/24/2018	6/22/2018	January 2019	Complete
Project 8	Anomalous Propagation Interference Analysis	Shared Spectrum Company	1/31/2018	2/13/2018	7	4/26/2018	6/13/2018	October, 2018	Complete
Project 9	Receiver Interference Thresholds	Next Phase Solutions and Services, Inc.	1/31/2018	2/22/2018	11	5/22/2018	9/22/2018	March, 2019	Complete
Project 2	RFI Analysis	Next Phase Solutions and Services, Inc.	4/13/2018	4/20/2018	9	7/20/2018	10/20/2018	December, 2018	Complete
Project 6	Survey of Receiving Equipment	Shared Spectrum Company	4/27/2018	5/24/2018	12	9/24/2018	5/09/2019	August, 2019	Site survey, data architecture and flow tracing continue, 78%
Project 11	LTE TDD Simulations, Passive Site Surveys, and Active Testing	Shared Spectrum Company	7/15/2018	7/18/18	9	11/29/2018	Shutdown	April, 2019	Complete
Project 3	ID Alternative Architectures	Shared Spectrum Company	7/16/2018	7/24/18	8.5	10/24/2018	Shutdown	June, 2019	Assessing 4 alternative architectures for DCS & GRB. 89% complete
Project 10	Interference Monitoring System Analysis	Shared Spectrum Company	10/29/2018	3/4/2019	9.5			January, 2020	Trade study and standards analysis tasks underway, 17%
Project 7	Requirements/Methods to protect downlinks	TBD	12/10/2018	5/27/2019	8			January, 2020	
Project 4	Develop costs for Alternative Architectures	TBD	4/19/2019	-	8.5			January, 2020	
Project 5	Alternative Satellite Downlink Communications	TBD	4/19/2019	-	6			January 2020	