Description of document: National Oceanic and Atmospheric Administration (NOAA) Reliability Analysis for NESDIS/GOES Earth Observation Satellite Constellation 2021

Requested date: 29-November-2021

Release date: 21-July-2022

Posted date: 10-October-2022

Source of document: Freedom of Information Request
National Oceanic and Atmospheric Administration
Public Reference Facility (SOU1000)
1315 East-West Highway (SSMC3)
Room 9719
Silver Spring, Maryland 20910
FOIA Online

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE, DATA,
AND INFORMATION SERVICE

July 21, 2022

Re: FOIA Request DOC-NOAA-[2022-000260]

This letter is in response to your Freedom of Information Act (FOIA) request entered into FOIAonline, our request tracking database, on November 29, 2021 in which you requested:

> "A copy of the most recent reliability analysis document(s) for extended weather observation life for GOES satellites on orbit for a minimum of one year, which is referenced in the enclosed NOAA Geostationary Satellite Programs Continuity slide. You may limit this to reliability analyses dated between January 1, 2020 and the present."

We are releasing the following document responsive to this request with the redactions noted.

- 2021 NESDIS Geostationary Reliability and Constellation Availability Report w Memo Redactions Applied.pdf

  All redactions in this document are made under one or more of the three exemptions listed below:

  - FOIA Exemption U.S.C.552(b)(3) which exempts from disclosure "Information prohibited from disclosure by another federal law. Additional resources for invoking Exemption 3 are available on the Department of Justice FOIA Resources page."
  - FOIA Exemption U.S.C.552(b)(4) which exempts from disclosure "Information concerning business trade secrets or other confidential commercial or financial information is exempt."
  - FOIA Exemption U.S.C.552(b)(5) which protects "inter-agency or intra-agency memorandums or letters which would not be available by law to a party other than an agency in litigation with the agency". As such, it has been construed to "exempt those documents, and only those documents that are normally privileged in the civil discovery context".
  - 11 pages are released in entirety and 21 pages are partially redacted.

You have the right to file an administrative appeal if you are not satisfied with our response to your FOIA request. All appeals should include a statement of the reasons why you believe the FOIA response was not satisfactory. An appeal based on documents in this release must be received within 90 calendar days of the date of this response letter at the following address:

Assistant General Counsel for Employment, Litigation, and Information
U.S. Department of Commerce Room 5896
1401 Constitution Ave. NW
Washington, DC 20230

An appeal may also be sent by email to FOIAAppeals@doc.gov or by FOIAonline at https://foiaonline.gov.

For your appeal to be complete, it must include the following items:

- a copy of the original request,
- our response to your request,
- a statement explaining why the determination was in error; and
- "Freedom of Information Act Appeal" must appear on your appeal letter. It should also be written on your envelope, email subject line, or your fax cover sheet.

FOIA appeals posted to the email box, FOIAonline, or Office after normal business hours will be deemed received on the next business day. If the 90th calendar day for submitting an appeal falls on a Saturday, Sunday or legal public holiday, an appeal received by 5:00 p.m., Eastern Time, the next business day will be deemed timely.

FOIA grants requesters the right to challenge an agency's final action in federal court. Before doing so, an adjudication of an administrative appeal is ordinarily required.

The Office of Government Information Services (OGIS), an office created within the National Archives and Records Administration, offers free mediation services to FOIA requesters. They may be contacted in any of the following ways:

Office of Government Information Services
National Archives and Records Administration
Room 2510
8601 Adelphi Road
College Park, MD 20740-6001

Email: ogis@nara.gov

Phone: 301-837-1996
Fax: 301-837-0348
Toll-free: 1-877-684-6448

If you have questions regarding this correspondence please contact Maria Burke at maria.burke@noaa.gov or by phone at (202) 308-4959, or the NOAA FOIA Public Liaison Tony LaVoi at tony.lavoi@noaa.gov or by phone at (843) 740-1274. Please refer to your FOIA request tracking number DOC-NOAA-2022-000260 when contacting us.

Sincerely,

Mark S. Paese

Mark S. Paese
Deputy Assistant Administrator for
Satellites and Information Services

Memorandum for the Record

Within NOAA's National Environmental Satellite Data and Information Service (NESDIS), the Office of Systems Architecture and Advanced Planning (OSAAP) is responsible for satellite reliability and constellation availability for NOAA-managed space assets. Calculation of each satellite's reliability is necessary in order to reasonably predict how long a set of satellites (constellation) will be available for use in the ensuring of continuity of weather observations.

OSAAP contracts the Aerospace Corporation, Civil Systems Group, to perform annual calculations of NOAA satellite reliability and constellation availability, and the planning and guidance for the analyses are guided by OSAAP management. The following report is the 2021 engineering assessment; OSAAP has reviewed and approved this final report.

AEROSPACE REPORT NO.
VTR-2022-00027

2021 Geostationary Reliability and Constellation Availability Assessment

October 5, 2021

Hang-kam Lee[1], Nikisa S. George[2], Rachael Quast[1]
[1]Reliability and Statistics Department, Mission Assurance Subdivision
[2]Systems Architecture and Engineering, Environmental Remote Sensing

Prepared for:

NOAA NESDIS OSAAP Headquarters
1335 East-West Highway
SSMC1 8th Floor
Silver Spring, MD 20910

Contract No. SP-133E-17-CQ-0020

Authorized by: Civil Systems Group

Acknowledgments

We acknowledge Phillip Jasper and Peter Phillips of The Aerospace Corporation; and Alexander Krimchansky and Thomas Kenney of GOES R team for providing their expertise on the GOES reliability modeling and reviews. We thank Jason Long, and Antonio Abadia of NOAA for providing their expertise on the DSCOVR satellite reliability modeling and reviews. We thank Phillip Jasper and Alexander Krimchansky for providing GOES satellite location assignments and launch strategies. We also acknowledge Christopher Wheeler the GOES-R Mission Operations Manager for providing fuel life estimates. And lastly, we thank Octavio M. Urista Benitez of The Aerospace Corporation on his consultation on constellation availability analyses.

Contents

Figures

Tables

1. Introduction

The National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite Data and Information Service (NESDIS) Line Office (LO) manages and operates Earth-observing space assets. NESDIS provides access to global environmental data from remote sensing satellites.

NESDIS GOES satellites provide continuous monitoring necessary for weather data analysis. They circle the Earth in a geosynchronous orbit, which means that they orbit the equatorial plane of the Earth at a speed matching the Earth's rotation. This allows the satellite to hover continuously over one position on the surface. The geosynchronous plane is about 35,800 km (22,300 miles) above the Earth, high enough to allow the satellites a full-disc view of the Earth. Furthermore, NOAA operates two primary geosynchronous satellites to cover the United States with continuous satellite imagery. GOES-East (13) orbits above the equator at 75W (same longitude as Philadelphia, PA), while GOES-West (15) orbits above the equator at 135W (same longitude as Juneau, AK).

This 2021 Geostationary satellite reliability and constellation assessment is an annual report under the stewardship of the NOAA/NESDIS's Office of Systems Architecture and Advanced Planning (OSAAP).

NESDIS United States (US) assets were the primary focus of this effort that includes satellite systems that provide weather monitoring and forecasting for North America. Thus, the scope of this effort was limited to GOES-13 (transferred to USAF), GOES-14, GEOS-15, GOES-16, GOES-17, and GOES-R satellites.

NOAA's Deep Space Climate Observatory (DSCOVR), America's first operational satellite in deep space, is included in the assessment as well. DSCOVR monitors solar winds in real time and is a warning system of solar magnetic storms. DSCOVR, operated by NOAA, is a partnership between NOAA, NASA, and the U.S. Air Force.

The fidelity of the GOES and DSCOVR satellite systems is critical to support the Nation's security, weather predictions, and other national and international services. This annual report provides updated data availability of the GOES spacecraft and its Key Performance Parameter (KPP) contributing instrument — the Imager. Aerospace consulted with the GOES-R Program Office to determine constellation scenarios and satellite assignments. DSCOVR data availability has also been updated and reviewed with the Program Office team.

Section 1.1 further reviews the purpose of the analyses and Section 1.2 summarizes the assumptions leveraged. Section 1.3 provides a comprehensive definition of constellation data availability. Section 2 provides a review of the sensor spacecraft and satellite reliability models. Constellation data availability with considered scenarios is provided in Section 3. Functional Availability of GOES satellites is provided in Section 4 followed by a summary of the study in Section 5.

1.1 Purpose of Analyses

Availability analyses implemented define current and future satellites in operational orbit capable of providing required data. Operational reliabilities have been assessed and the combined reliabilities of these satellites have been calculated to determine availability success probabilities for four scenarios.

1.2 Assumptions

The analyses assume current satellites in the constellation operate continuously until a critical failure or planned de-orbit due to fuel depletion. Analyses include failure modes (components) identified to date.

Reliability Contract Data Requirements Lists (CDRLs) provided by the Program Office were used in this study. Logical assumptions were leveraged in the absence of data at the time of this study.

2021 results reflect satellite and constellation status and data availability as of 1 August 2021. Any anomalies, flight system configuration, and launch schedule changes after this date have not been incorporated in the 2021 assessment.

Mission reliabilities of future to-be-launched, satellites include manifested or assumed launch vehicle success probabilities. Future GOES-series satellites assume Atlas-equivalent launch vehicles.

1.3 Definition of Constellation Data Availability

Constellation Data Availability is defined as the probability that specified geostationary satellites will provide KPP-Imager or KPP-replacement data to the ground data input point. A data gap is the opposite of data availability; it is a loss of capability to provide KPP data; as availabilities are success probabilities (Ps's), the probability of a data gap is 1 – Ps.

KPP instruments are Visible (Vis) imagers for GOES-13, -14, -15 and Advanced Baseline imager (ABI) for the GOES-R series.

For these analyses, the ground system probability of success (Ps) is assumed to be 1.0 (100%) because ground system anomalies and/or failures can be corrected and/or repaired to restore full functional capability without data loss.

2. Sensor, Spacecraft, Satellite, and Constellation Models

Assessing GOES Constellation and DSCOVR Data Availability requires developing models in a three-step process. First, instrument (sensor) and spacecraft bus reliability models are derived; typically, these are independent analyses and models. These results provide both operational reliability logic and reliability mathematical models that predict element (spacecraft, instrument) reliability versus operating time. Then, instrument models are incorporated into spacecraft bus models to provide satellite models. Satellite models provide reliability estimates based on the satellite's design and operation. Satellite models in the current assessments include only KPP instruments (or functional replacements) for each satellite model. A satellite may include other instruments in its payload; however, only the KPP or KPP replacement instruments are used in the models and scenarios within this assessment. Finally, satellite models are incorporated as input elements into constellation models. Constellation models are derived and built for defined scenarios and timeframes (refer to Section 3).

Reliability modeling accounts for random (typically associated with useful life) and wear-out (increasing) failure rates. Parts or components that are thought to not age or wear-out during a mission's lifetime have random, or constant, failure rates. Components or parts that age while in service have wear-out failure rates; these occur by mechanical stresses (e.g., bearings), degraded performance (e.g., batteries), or resource depletion (e.g., fuel, lubricants, etc.). Element reliabilities are updated by times in service (i.e., operating times on-orbit). Component and/or system failure rates are adjusted for any functional or redundancy loss. Additional wear-out failure modes are incorporated when identified. Reliability models are basic elements in availability models; they are used in constellation availability calculations. Formally, availability applies only to repairable components or systems. In the context of this analysis, substitute elements are available on-orbit to replace ("repair") any failed system elements; hence, the term availability is used.

Spacecraft models herein refer to a spacecraft bus without its manifested sensors (instruments), also called "the payload" (or all instruments aboard the spacecraft). Sensor (or instrument) models refer to models for the individual sensors (Imager). Instruments (sensors) carried aboard spacecraft are combined with bus models to form satellite models. The satellite models are used in the constellation availability scenarios and cases within scenarios. In other words, a constellation model is a combination of two or more spacecraft models for geostationary constellation cases.

Results from the constellation models provide planning and management information for the geostationary weather satellite constellation by predicting constellation availability over moderate- to long-term timeframes. These estimates provide input for planning future satellite replenishment dates.

Future, to-be-launched, satellites include launch vehicle success probabilities in their predicted reliabilities. Remaining GOES-R and follow-on satellites are assumed to launch on Atlas V or similar vehicles. [redacted]

Redactions in Section 2 are due to Exemption 3: Information subject to Export Control.

2.1 GOES-13 (EWS-G1), GOES-14 and GOES-15 Satellite Reliability Model

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Figure 1. GOES-13 (EWS-G1) satellite reliability.

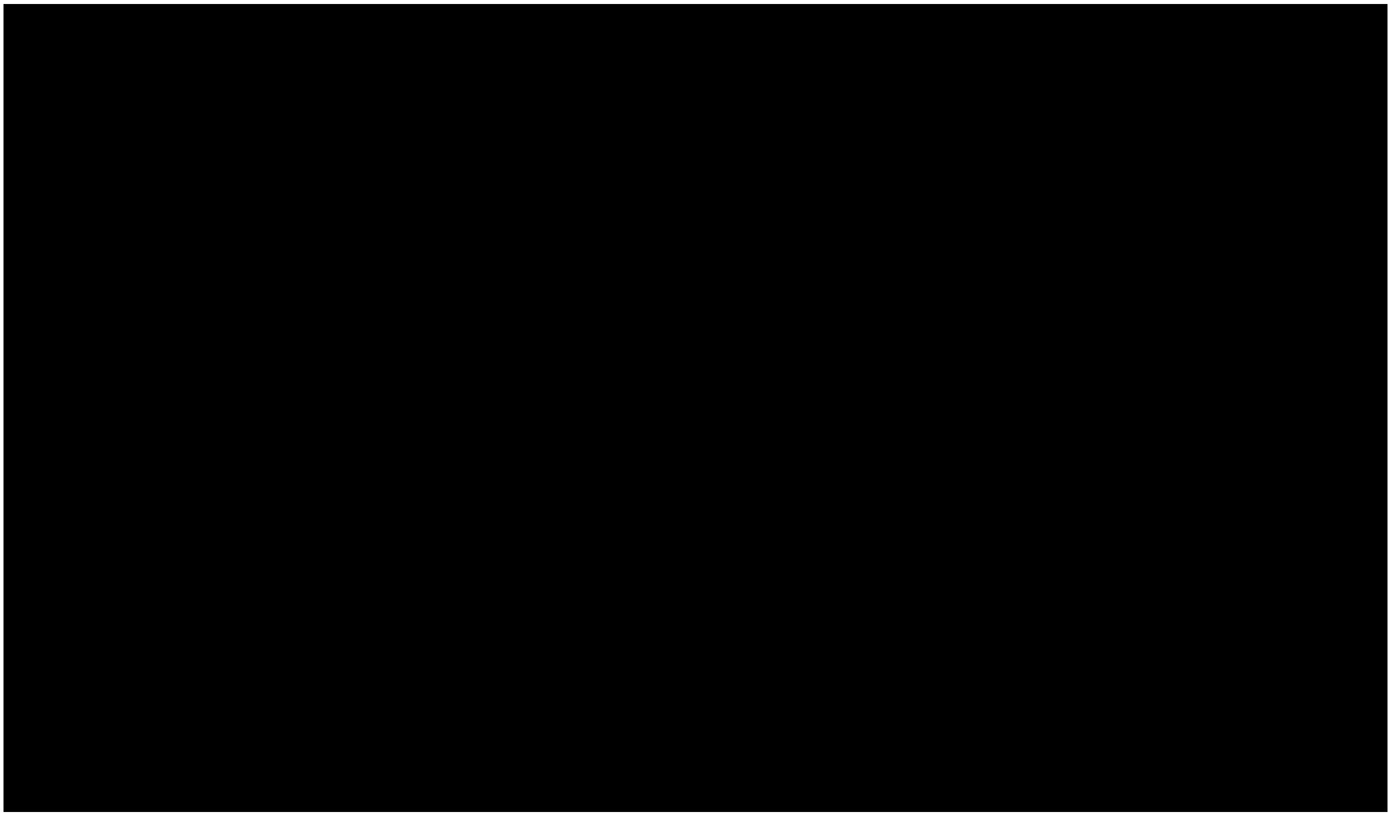

Figure 2. GOES-13 (EWS-G1) 2020 vs. 2021 satellite reliability.

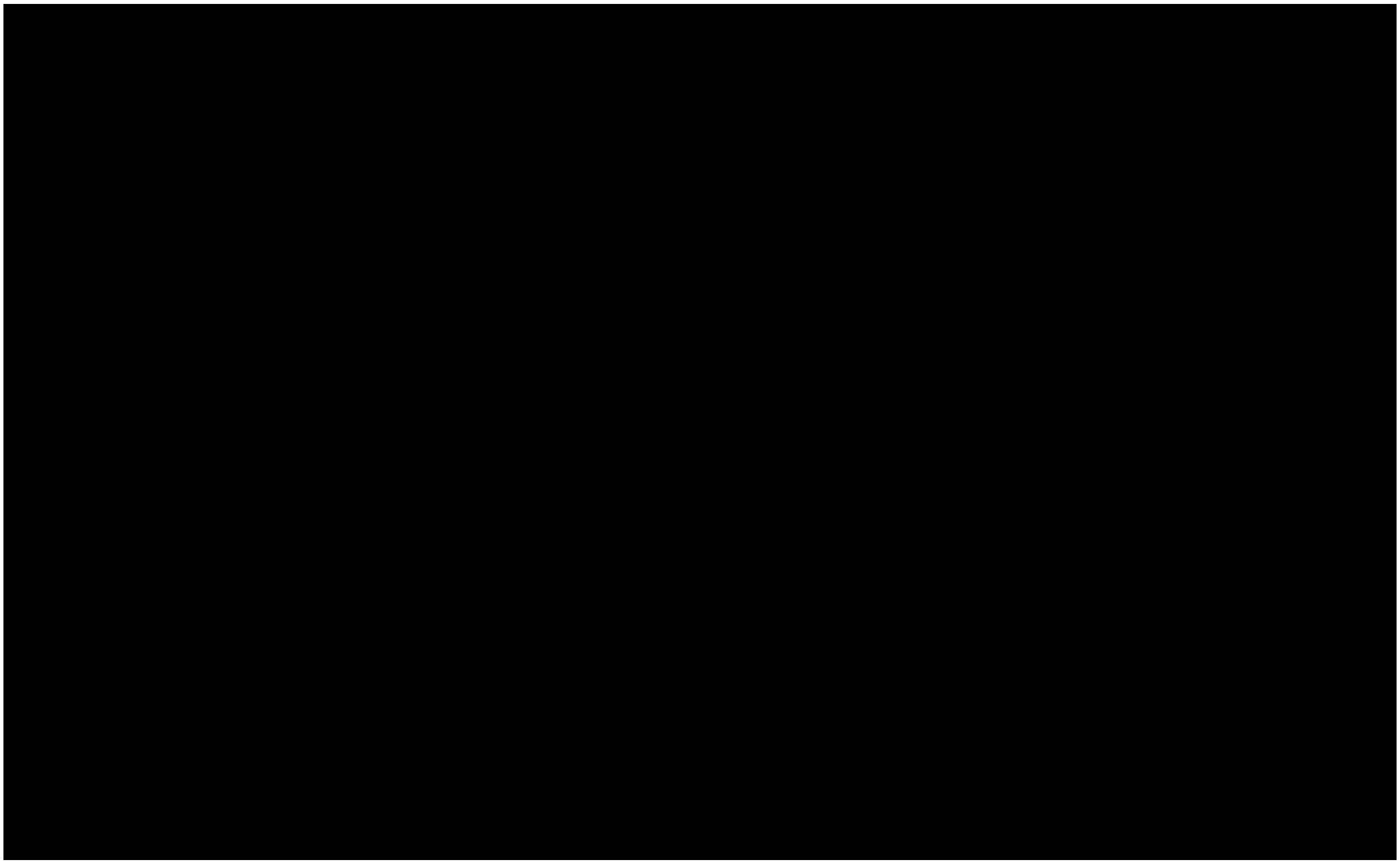

Figure 3. GOES-14 satellite reliability.

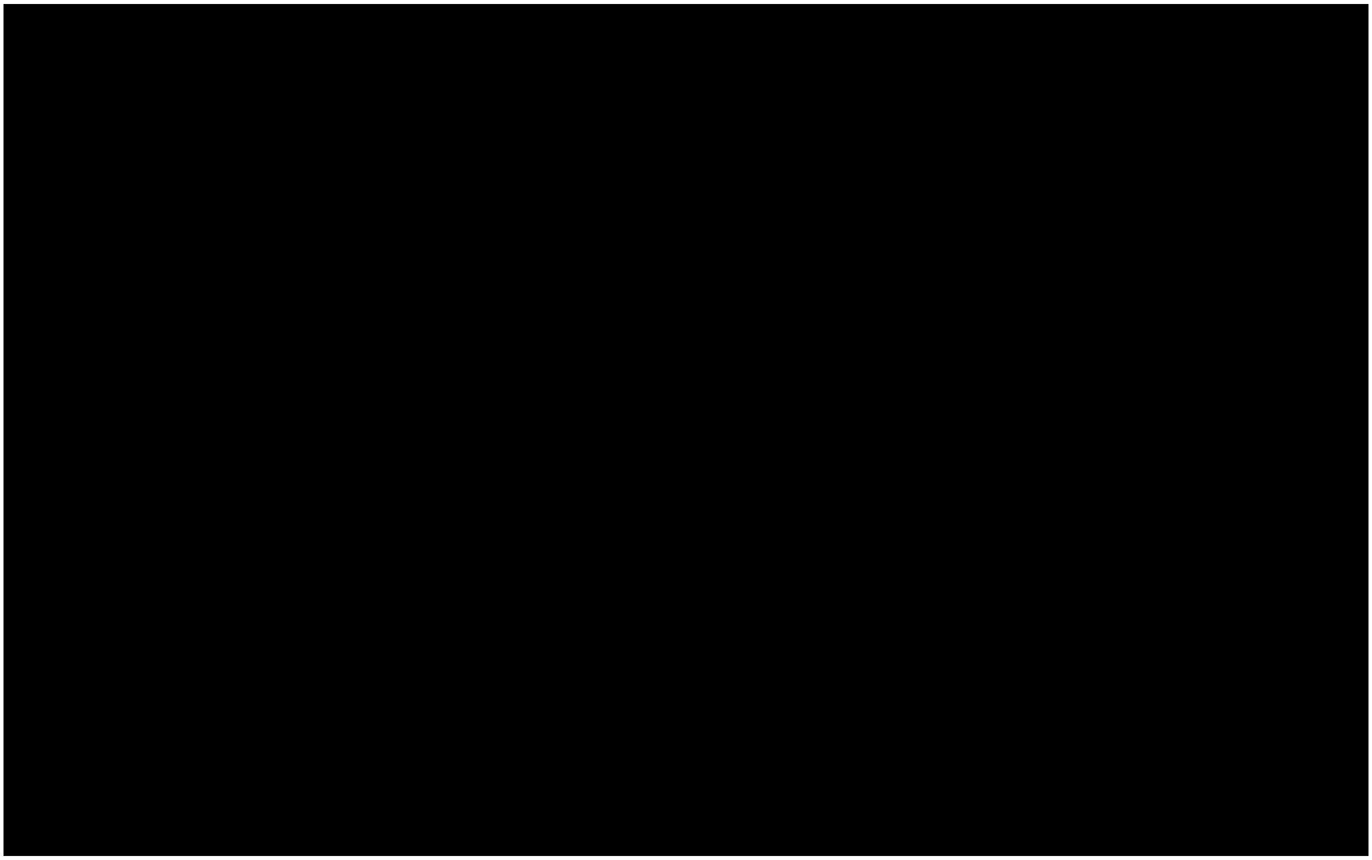

Figure 4. GOES-14 2020 vs. 2021 satellite reliability.

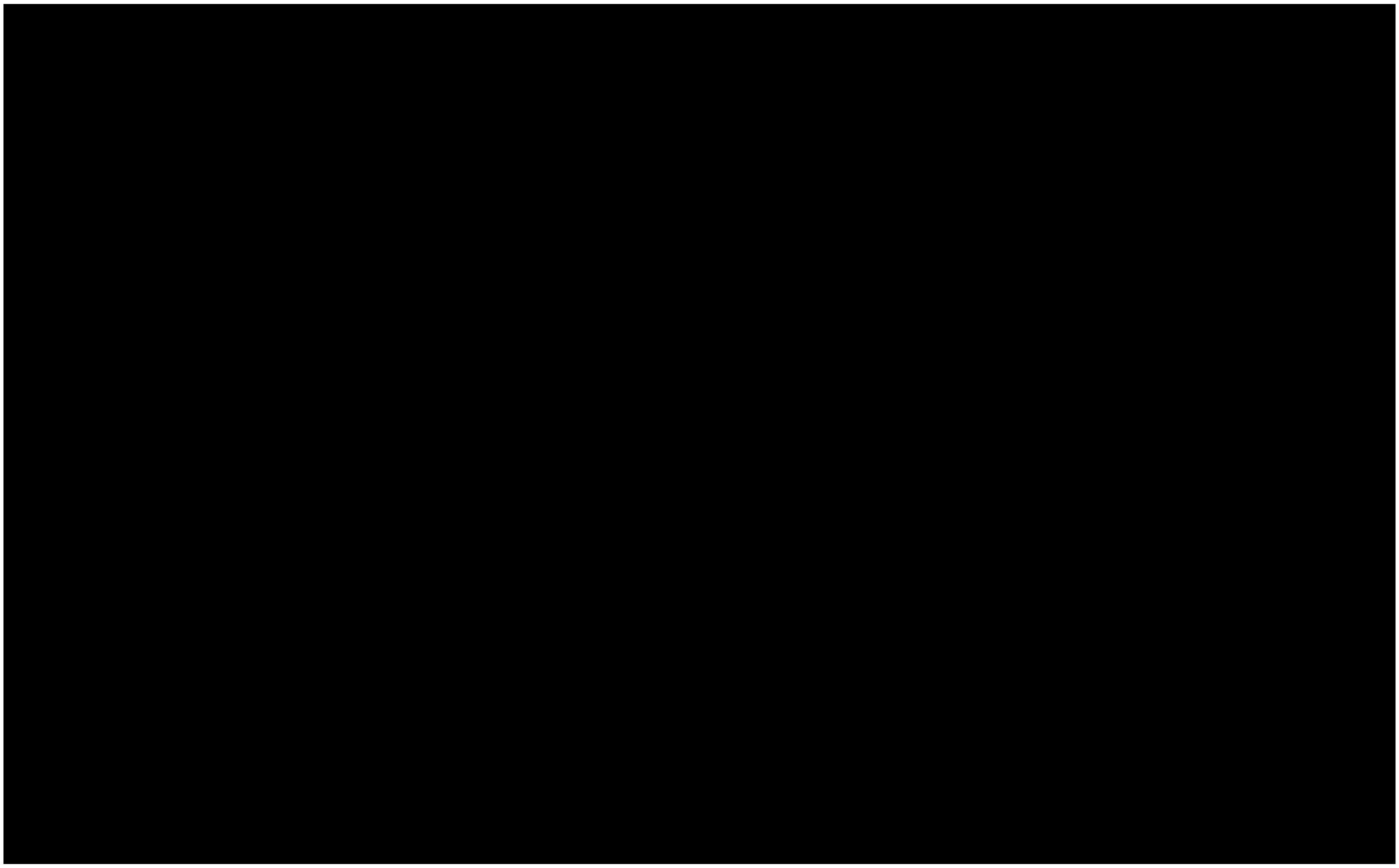

Figure 5. GOES-15 satellite reliability.

[redacted]

Figure 6. GOES-15 2020 vs. 2021 satellite reliability.

All redactions in Section 2.1 are due to Exemption 3: Information subject to Export Control.

2.2 GOES-16 and GOES-17 Satellite Reliability Models

ABI (advanced baseline imager) is the KPP imager for GOES R. There is no change on the GOES-16 ABI, and on-orbit success is reflected on 2021 reliability models. For 2021, reliability for GOES-17 ABI is changed to reflect modified storage configuration (GOES-17 will be in storage mode after GOES-T becomes the primary satellite (after successful launch and calibration) [redacted]

[redacted]

[redacted] **All redactions in Section 2.2 are due to Exemption 4: Proprietary Information and Exemption 3: Information subject to Export Control.**

2.3 On-orbit Assets: GOES-R (GOES-16 & GOES-17) Satellite Reliabilities

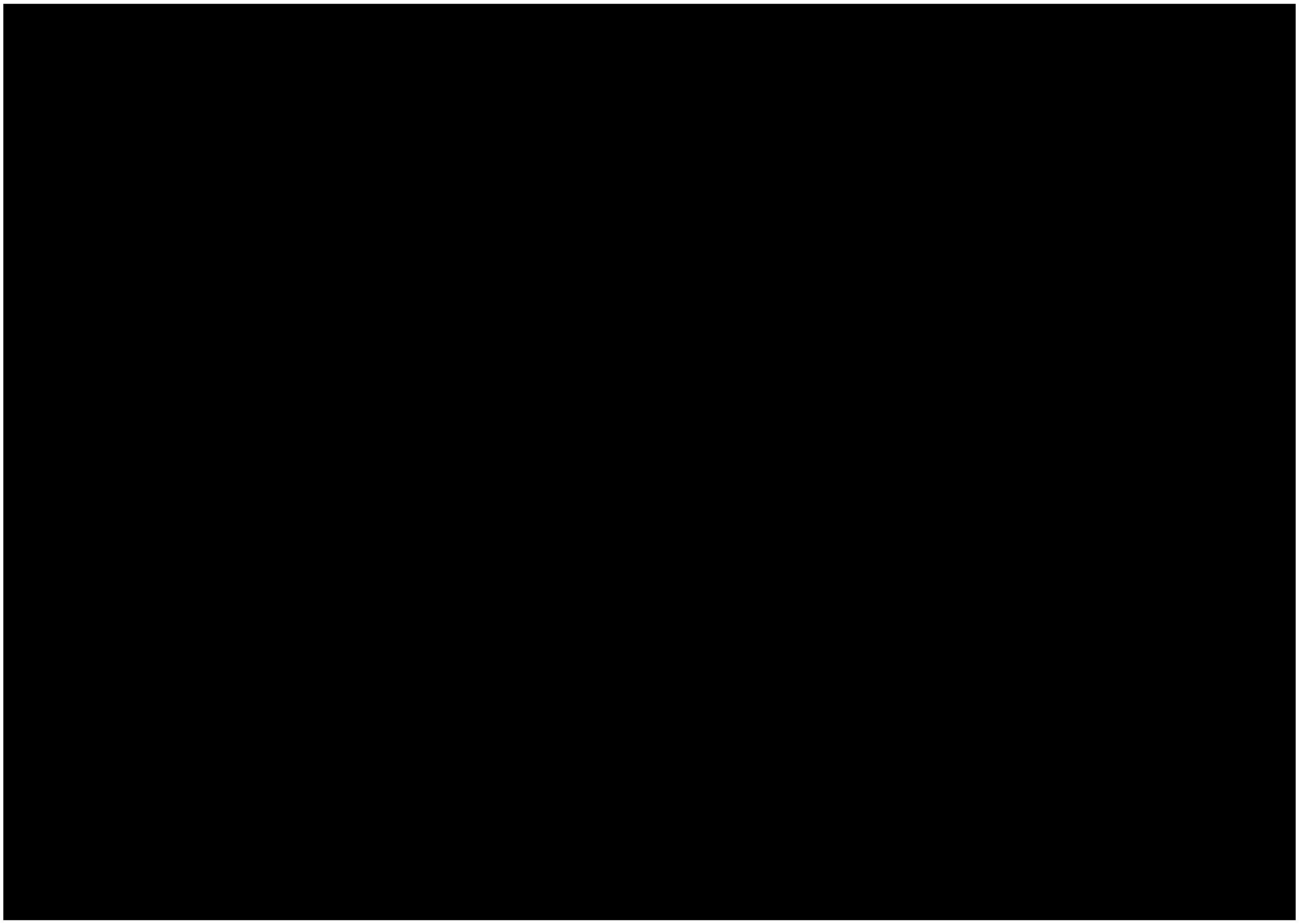

Figure 7. GOES-16 satellite reliability.

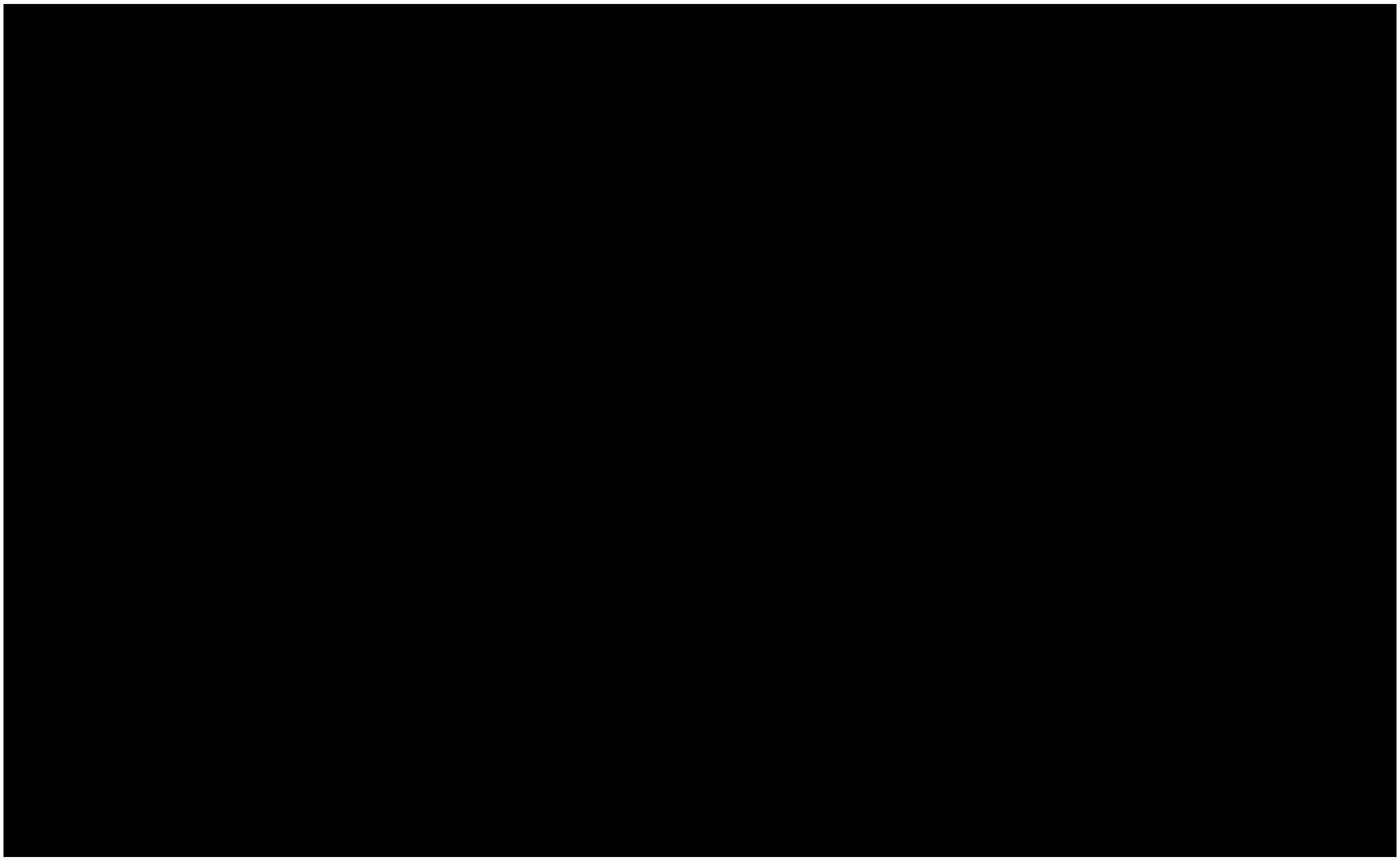

Figure 8. GOES-16 2020 vs. 2021 satellite reliability.

[redacted]

Figure 9. GOES-17 satellite reliability.

[redacted]

Figure 10. GOES-17 2020 vs. 2021 satellite reliability.

All redactions in Section 2.3 are due to Exemption 3: Export Control.

2.4 GOES Input Parameters

Tables 1 and 2 list GOES reliability distribution parameters. [redacted]

Table 1. GOES Operational Reliability Parameters

[redacted]

Table 2. GOES Operational Reliability Parameters

[redacted]

[redacted] **All redactions in Section 2.4 are due to Exemption 3: Proprietary Information and Exemption 4: Export Control (with the exception of Table 3).**

Table 3. GOES-13, -14, and -15 Life Estimation Dates

[redacted]

Table 3 redactions are due to Exemption 3: Export Control and Exemption 5: Pre-decisional.

[redacted]

Figure 11. GOES-T, -U satellite reliability.

All redactions in Section 2.5 are due to Exemption 4: Proprietary Information and Exemption 3: Information subject to Export Control.

3. DSCOVR Satellite Reliability

DSCOVR was launched in February 11, 2015. Plasma-Magnetometer (Plas-mag) is the primary instrument that measures solar wind for space weather predictions. It is positioned in L1 where the gravitational attraction of Earth partially cancels the attraction of the sun. This gives DSCOVR the same orbital period as Earth and allows for year-round, full-view imagery of Earth. It has a mission life of two years.

The reliability model is the same as that in 2020 with credit given to successful on-orbit operation. No critical failures have been identified since the 2020 update. Furthermore, fuel life has been updated and was provided by the DSCOVR program team on May 2021.

[redacted]

Table 4. DSCOVR Reliability

[redacted]

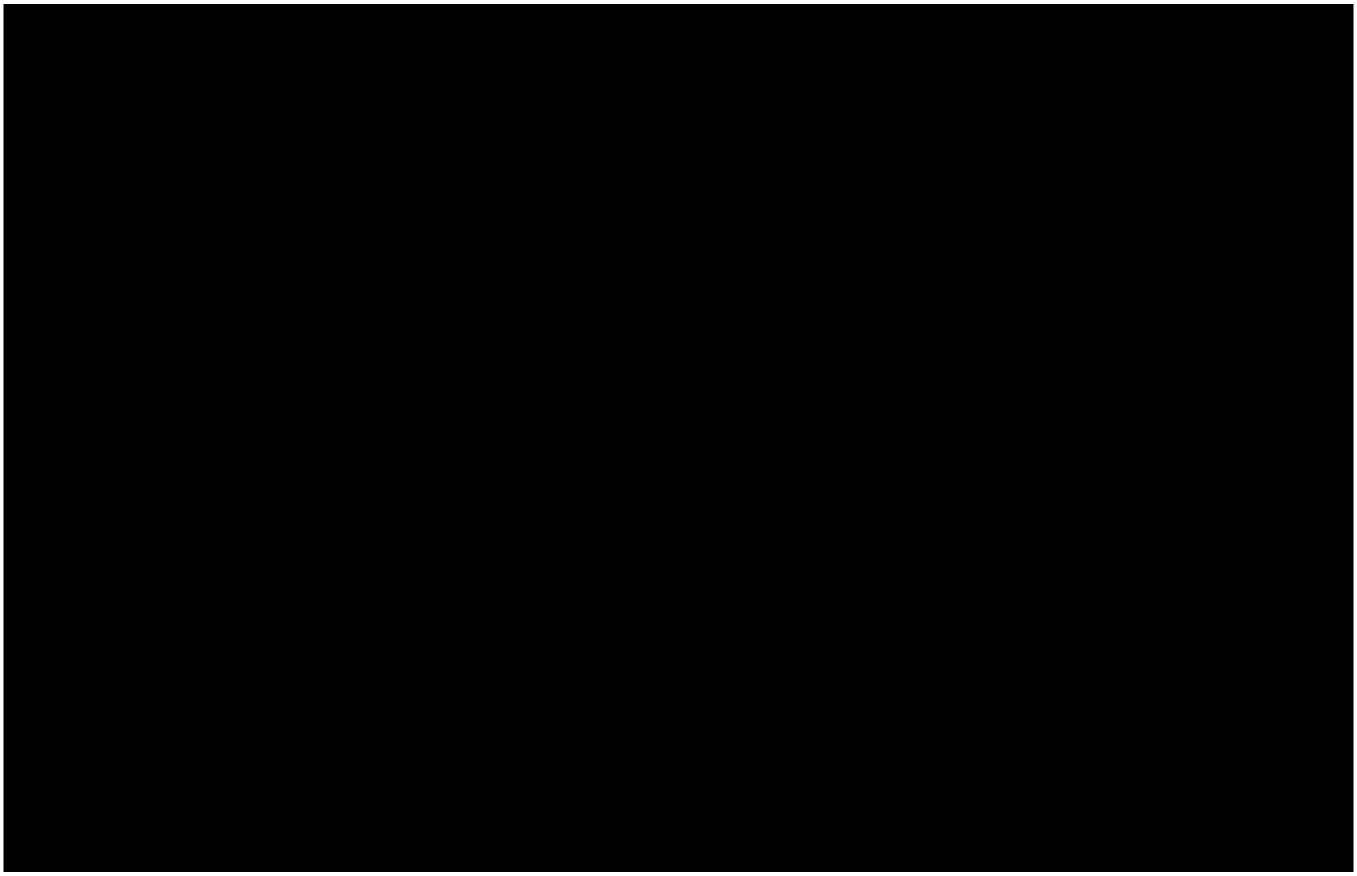

Figure 12. DSCOVR satellite reliability.

Figure 13 shows the DSCOVR comparison of reliability estimates between 2020 and 2021.

[redacted]

Figure 13. DSCOVR 2020 vs. 2021 satellite reliability.

All redactions in Section 3 are due to Exemption 4: Proprietary Information and Exemption 3: Information subject to Export Control.

4. GOES Constellation Data Availability Models

Satellite models and reliabilities reviewed in Section 2 are input parameters for constellation availability models and computed availabilities. The 2021 Geostationary Constellation Availability models have been generated using R, which is an open-source software environment for statistical computing. Statistical data from R was then exported to a workbook and graphics were generated.

4.1 Constellation Data Availability Assessment

[redacted]

4.2 Constellation Scenarios

[redacted]

[redacted]

4.3 Constellation Availability Results

[redacted]

Figure 14. Scenario 1.

[redacted]

Figure 15. Scenario 2.

[redacted]

Figure 16. Scenario 3.

[redacted]

Figure 17. Scenario 4.

All redactions in Section 4 are due to Exemption 3: Export Control and Exemption 5: Predecisional.

5. Mean Life Estimates

The following tables shows Mean Life Expected (MLE) for GOES satellites and DSCOVR.

Table 5. Mean Life Estimates (MLE): GOES Satellites Each with an Imager

[redacted]

Table 6. Mean Life Estimates (MLE): DSCOVR

[redacted]

All redactions in Section 5 are due to Exemption 3: Information Subject to Export Control, Exemption 4: Proprietary Information and Exemption 5: Predecisional.

6. Summary

2021 satellite reliability and constellation availability has been reviewed for NESDIS US geostationary satellite systems. 2021 results reflect satellite and constellation status and data availability as of 1 August 2021 (end date of the analysis in this study). GOES-R reliability models provided by the GOES-R program office have been leveraged in this effort. Furthermore, GOES-R program office management was consulted to determine constellation scenarios and currently projected launch dates. During task execution, reviews were held to ensure analyses and modeling were performed to generally accepted reliability and availability analysis standards and that consistent assumptions were applied to the instruments, spacecraft, and satellites.

Future work includes updating GOES-T and -U reliability models if reliability CDRLs are made available. Continued consultation with the GOES program team will continue to ensure the latest wear-out reliability items are considered.

7. References

1. Lee, Hang-Kam and Nikisa George, "2020 Geostationary Reliability and Constellation Availability Assessment." Aerospace Report No. VTR-2021-00354. The Aerospace Corporation, November 30, 2020.

2. "NOAA/NESDIS Satellite Extended Life Estimation Policy." NESDIS-PD-1060.1, August 2017. https://www.nesdis.noaa.gov/sites/g/files/anmtlf151/files/2021-08/NESDIS_Extended_Life_Policy_Nov_7_2017.pdf Accessed 30 September 2021.

External Distribution

REPORT TITLE		
2021 Geostationary Reliability and Constellation Availability Assessment		
REPORT NO.	PUBLICATION DATE	SECURITY CLASSIFICATION
VTR-2022-00027	October 29, 2021	UNCLASSIFIED

Dan St. Jean
NOAA
dan.stjean@noaa.gov

Mordechai Cohen
NOAA
mordechai.cohen@noaa.gov

APPROVED BY____ DATE______________

AEROSPACE REPORT NO.
VTR-2022-00027

2021 Geostationary Reliability and Constellation Availability Assessment

Approved Electronically by:

Michael R. Moore, DIRECTOR
MISSION ASSURANCE SUBDIVISION
SYSTEMS ENGINEERING DIVISION
ENGINEERING & TECHNOLOGY GROUP

Cognizant Program Manager Approval:

Ingrid C. Paluch, SYSTEMS DIRECTOR
ENVIRONMENTAL REMOTE SENSING
CIVIL SPACE PROGRAMS OPERATIONS DIVISION
CIVIL SYSTEMS GROUP

Content Concurrence Provided Electronically by:

Nikisa S. George, SENIOR PROJECT LEADER
SYSTEMS ARCHITECTURE & ENGINEERING DIR
ENVIRONMENTAL REMOTE SENSING
CIVIL SYSTEMS GROUP

Technical Peer Review Performed by:

Phillip C. Jasper, SENIOR PROJECT ENGINEER
GOES FLIGHT SYSTEMS
OPERATIONAL PROGRAMS DIRECTORATE
CIVIL SYSTEMS GROUP

SI0682