

NASA/CR-20210023817



EED-2 Contract Final Report

Peter Plofchan

November 2021

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Peter Plofchan
Raytheon Company, Riverdale, MD

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

November 2021

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NASA's Langley Research
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National Technical Information
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Springfield, VA 22161
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EED-2 CONTRACT FINAL REPORT

Submittal Date:	09/10/2021	
Program Title:	Earth Observing System Data and Information System (EOSDIS) Evolution and Development – 2 (EED-2)	
GSFC COTR:	Name: Steve Berrick	Phone: (301) 614-5924
	Email: stephen.w.berrick@nasa.gov	
Program Manager:	Name: Peter Plofchan	Phone: (301) 851-8194
	Email: peter.g.plofchan@raytheon.com	

1. Introduction

This document is the Final report for the Earth Observing System Data and Information System (EOSDIS) Evolution and Development – 2 (EED-2) contract. This is a formal document contract deliverable and is in compliance with EED-2 contract clause H.13(a) Final Report requirement. This report summarizes the results of the entire program.

2. Program Description

This contract provides for development and sustaining engineering of software and hardware systems that provide science data management for the ESDIS Project. A major activity under this contract will be for evolution and development engineering of the EOSDIS Core System (ECS), Earthdata platform, Common Metadata Repository (CMR), NASA-Compliant General Application Platform (NGAP) cloud environment, and other EOSDIS elements that provide the common capabilities and infrastructure of EOSDIS.

3. Period of Performance

Start Date: 9/1/2015

End Date: 7/31/2021

4. Program Performance Summary

The EED-2 team has performed outstanding work throughout the entire contract Period of Performance and has streamlined processes in development and sustaining engineering for all the operational components of EED systems. The team's continual involvement of stakeholders was a major factor to EOSDIS receiving high scores from the American Customer Satisfaction Index (ACSI) survey. Additionally, the high technical expertise provided by the EED-2 team in the areas of search and publication contributed to Terra winning the 2019 Pecora Award for invaluable contributions in all areas of Earth science.

The EED-2 program was funded through fifty-two discrete tasks. Performance for each task is summarized below.

Task 01 – EED to EED2 Transition (Phase-In)

Under this task, Raytheon retagged all EED property at Riverdale, GSFC, ASDC, LP DAAC, and NSIDC, submitted an updated IT Security Management Plan, submitted the initial PIV report, and established the EED-2 control account.

A detailed report of activities completed under this task can be found in the Task 01 Final Task Report (EED2-FTR-001), dated 10/30/2015.

Task 02 – SDPS Sustaining Engineering and Continuous Evolution

Under this task, Raytheon managed the program through estimation review of proposals, integrated resource planning to ensure required staffing, and complete vetting of assumptions and risks with any proposals. The EED-2 program manager held weekly meetings with NASA's ESDIS COTR to review any programmatic issues and advised of any program decisions, plans, and issues. Program planning occurred essentially at the task level and was integrated into the agile planning for each task. Customer involvement in task planning is a key part of the agile process, and Raytheon included the customer in the planning to prioritize and understand operational delivery plans.

Sustaining engineering metrics demonstrate that Raytheon was very responsive to priority problems, and that problems were fixed correctly without additional breakage. The metrics reflect the team's excellent performance with respect to delivery of patches, test executables, and routine COTS upgrades.

Raytheon managed the EED-2 Program under an ISO 9001:2008 Quality Management System (QMS) certificate, which provides NASA with the assurance that the program is supported by an externally certified quality system that meets or exceeds contract requirements.

Raytheon sustained a stable and robust Release 8.3 baseline at the DAACs and produced 6 Releases of the SDPS software (8.3.6, 8.3.7, 8.3.8, 8.4, 8.4.1 and 8.4.2). Raytheon provided extensive support to subsetting, reformatting, and reprojecting Earth Science data. This support included evolving the HDF-EOS to GeoTIFF Conversion Tool (HEG) to process SMAP Level 3 and 4 HDF5 products, providing KML reformat generation and testing, improving processing functionality of the SMAP product, and providing reprojection support for SMAP L1/L2 data.

Raytheon effectively led key NASA activities related to the ISO TC211 committee. The team led the 19115-3, 19157-2, and 19139-1 project teams and the ISO TC211 XML Management Group. Raytheon also represented ESDIS in Federal and International discussions related to adoption and implementation of ISO TC 211 and other standards and conventions.

Raytheon supported the MEaSUREs, MODIS, MOPITT, SMAP, and VIIRS missions and instruments by delivering new and updated ESDTs. Raytheon improved ESDT tools and resources by releasing HEG version 2.13, which supported batch processing, SMAP Level 3 and 4 HDF5 products, HDF-EOS5 grid products, and new MODIS and AMSR products.

Raytheon assisted ASDC as a result of DAAC staffing reductions and migrated EED-2 hardware as part of NSIDC's data center move. Raytheon also provided technical support to the HDF4 and HDF5 communities via the HDF Helpdesk, resolving 95.4% requests within one week of receipt.

Raytheon's Security team adhered to all contract security requirements and provided a protected, safe work environment. The team updated or deployed software to mitigate security vulnerabilities and to enhance our security posture and ensured that all EED-2 operating systems were patched in a timely manner, usually within 30 days. The team also facilitated the weekly Technical Security Information Working Group (TSIWG) meetings, providing an open forum for the interchange of information impacting the EED-2 subsystems.

Raytheon generated 107 hardware / software procurements. The team received all materials that were approved for shipment to ECS DAACs without any discrepancies and delays, and the receiving NASA Site Property Custodians confirmed receipt of all deliveries and reported no impact to their day-to-day tasking.

For the DAAC capacity increase and technology refresh, Raytheon helped LP DAAC, NSIDC, and ASDC maintain archive growth estimates and prepare sizing estimates for additional data storage that will be required in the upcoming years. Following these assessments, Raytheon procured and installed the necessary hardware at each DAAC.

A detailed report of activities completed under this task can be found in the Task 02 Final Task Report (EED2-FTR-002), dated 10/31/2016.

Task 03 – Earthdata

Under this task, Raytheon developed, evolved, and sustained software for the following subsystems:

- The Earthdata website at earthdata.nasa.gov.
- The Earthdata user interface (EUI).
- Earthdata Search.
- The Conduit Content Management System (CMS).
- The user feedback module.
- The Earthdata Login system (formerly User Registration System).
- The Earthdata Code Collaboratory (ECC).

Raytheon expanded the concept of the Web Infrastructure team to include program-wide services such as the support and operations for the Atlassian suite (JIRA, Confluence, STASH, HipChat, and Bamboo), Jama, and Kayako; and all supporting IT hardware, software (custom and COTS), and related tools required for developing and hosting web-based applications and the continuous deployment process. Raytheon rolled out the developer's portal concept, implemented the Status application, and continued to automate the software delivery process for all of Earthdata. All services averaged a 99.91% uptime. Raytheon also rolled out the Earthdata Enterprise Configuration System (EECS) and the new Earthdata developer's website (developer.ngap.earthdata.nasa.gov).

Raytheon enhanced and maintained the deployment stack suite of tools, introducing the Sonatype Nexus repository and the RedHat 7 operating system, which supports Docker container instances. These additions allowed the deployment stack support of simultaneous builds and reduced overall build time for the CMR application by 50%.

Raytheon completed version 1.0 of the Earthdata Status application and integrated it across Earthdata. This new feature allows for general and emergency notification messages / banners to appear on any integrated site. Raytheon also developed and implemented both the Sidebar Customization (creating lists of custom links and adding them to specific CMS pages) and the

Background Selection (selecting a background/theme for a section of the Earthdata site). Raytheon completed the Open Sourcing of the Conduit source code for CMS and added a new workflow and additional content type and page layouts. Finally, Raytheon enhanced the Earthdata User Interface (EUI) library to allow for broader interoperability with existing applications.

Raytheon managed the operations of the Earthdata environments by performing activities such as weekly patching, continuous monitoring, and change management. Raytheon also supported the infrastructure and deployment tool suite for the Sea Level Change Portal.

Raytheon also supported Earthdata Login operations, including system administration and helpdesk functionality, planning and execution of periodic system maintenance and system upgrades, monitoring to support metrics collection, trouble ticket management, and support to patches and releases. The production system experienced an increase of over 66,000 users, with weekly user growth averaging roughly 1,000 users. The system served approximately 1.7 million authentications per week and provided consistently high availability 99.97% from October 2015 – March 2016 and 99.98% from April – September 2016. Raytheon completed the integration of the Sea Level Change Portal with the User Support Tool (Kayako) and integrated twelve DAAC applications to Earthdata Login.

The Earthdata Login production system served as the central system for all EOSDIS user registration and authentication functions and provided 24x7 availability. The system supported user authentication and SSO capabilities based on the OAuth2 specification and API.

Raytheon maintained the development, test, and production environments by performing activities such as weekly patching, continuous monitoring, and change management. In order to sustain a compliant and low risk security posture, Raytheon's security team assessed the security configuration status of the Sea Level Change Portal (SLCP) UAT, and Kayako virtual machines (VMs). The team also installed software to prevent malware transitioning from NASCOM mail server and Kayako (support-ops1) server and verified blocking of file attachment types (i.e. .doc,.exe,.js,.jar).

Raytheon migrated the Earthdata Login webpages to follow the Earthdata EUI, whose framework incorporates 508 standards. Raytheon contracted with Blink UX to perform a UI/UX evaluation of the Sea Level Change Portal application. The review was focused around the Data Analysis Tools and the portal's browse functionality. Blink UX also performed a UI/UX review and evaluation of twelve DAAC websites with a focus on common user interactions, including the discovery and searching of data, getting data, and visualizing data. Both projects were comprised of both in-person and web-based interviews and provided detailed recommendation for design improvements.

A detailed report of activities completed under this task can found in the Task 03 Final Task Report (EED2-FTR-003), dated 10/31/2016.

Task 04 – S-NPP / SDS / SD3E Operations and Sustaining Engineering

Under this task, Raytheon provided support for daily SD3E operations, decommissioning of the SD3E system, and various systems engineering and interface testing activities in support of JPSS joint test activities. This included ingesting data from Interface Data Processing Segment (IDPS), Comprehensive Large Array-data Stewardship System (CLASS) and Government Resource for Algorithm Verification, Independent Testing, and Evaluation (GRAVITE) systems and making the data products available to the Science Investigator-led Processing Systems (SIPS).

Raytheon participated in the JPSS System Integration & Test Working Groups (SITWGs) and supported the JPSS joint test planning and coordination activities to ensure that the SD3E system met the operations and interface requirements for the JPSS system. Raytheon also participated in a number of mission partner coordination and planning meetings from the point of view of the Science Data Segment (SDS) and SD3E component, and supported JPSS Block 2.0 test events, including Operations Based Site Acceptance Testing (OBSAT) / Joint Test Run for Record (RFR) activities.

Raytheon worked with ESDIS task monitor and determined that the decommissioned SD3E hardware platforms could be repurposed and put to good use in support of the Sentinel Gateway task (Task 6). Subsequently, five Dell servers including three Dell R720 class servers and two Dell R620 class servers, were transferred to Task 6.

A detailed report of activities completed under this task can found in the Task 04 Final Task Report (EED2-FTR-004), dated 10/31/2016.

Task 05 – Common Metadata Repository

Under this task, Raytheon team provided excellent resource management to the Common Metadata Repository (CMR). Three major activities were concurrently accomplished: GCMD Search Functionality Cutover, Metadata Reconciliation, and continuation of the ECHO Shutdown. Raytheon also improved the Metadata Management Tool (MMT) through Beta testing with DAACs, improved the Earthdata Search Client (EDSC) by adding the ability to discover OPeNDAP endpoints and producing Discipline Specific Views, and improved CMR Metadata quality with a new change process allowing for a shorter review cycle of changes to UMM documents and adding the ability to humanize metadata.

Raytheon's Program Controls team monitored the task using the Earned Value Management System (EVMS) to ensure that technical task performance, schedule deadlines, and cost requirements were met. Raytheon provided weekly status briefings and monthly program management reviews to ESDIS on UMM, CMR/MMT/EDSC and ECHO/Reverb/PUMP, both technical and cost.

The resolution of CMR-3068 and EDO-844 in release CMR 1.54 delivered significant performance improvements for collection search at the 95th and 99th percentile. Improvements to hierarchical facet searching in CMR 1.54 (Version 2 of facet API) and Earthdata Search 1.23 (usage of new facet API by EDSC) further improved performance at the 99th percentile.

For the GCMD Search Functionality Cutover, Raytheon collaborated with the GCMD team to ensure that all of their must-have requirements were delivered on schedule and any critical bugs reported by the GCMD team were responded to within the next two-week sprint cycle. These efforts ensured a seamless systems integration of the legacy ECHO and GCMD systems.

For Metadata Reconciliation, Raytheon worked to reconcile the underlying collection-level metadata between the GCMD and the CMR. In order to accomplish this, the team facilitated monthly reconciliation telecons which enabled the DAACs to learn from each other and allowed Raytheon to answer questions and provide guidance on best practices. Raytheon also analyzed existing DAAC metadata holdings and data distribution systems for GHRC, MODAPS, ORNL and SEDAC to identify and resolve problems related to this merge effort.

Raytheon shut down ECHO's elastic search nodes and removed the metadata holdings from ECHO's Oracle instance. This allowed the reduction of maintenance periods by 50% due to the decreased number of virtual machines requiring patching.

In preparation for the Metadata Management Tool's operational release, Raytheon conducted a Beta testing activity with CDDIS, GCMD, GHRC, LAADS, LARC, LPDAAC, GES DISC, NSIDC, ORNL, SDPS and USGS potential users. Raytheon modified the CMR to provide validation against the UMM-Collection metadata on ingest, which allow providers to improve metadata quality on local systems and presented this new functionality at the Summer ESIP.

Raytheon transitioned the Earthdata Search application from beta to production. This application is now subject to the same deployment schedule as other Earthdata applications allowing for more efficient deployment with zero-downtime. The CMR micro service Access-Control was deployed to Operations, and all providers have completed the transition to CMR REST ingest. Transition of ECHO services by the development and operations teams to CMR increases the stability and performance of those services by leveraging the CMR infrastructure.

Raytheon's Security team performed monthly non-credential scans of all EED-2 hosts and remediated issues based on the level of severity with high and medium vulnerabilities findings getting immediate attention.

Raytheon procured and added 128 GB of memory to the ECHO/CMR HP BL465c G7 BladeServers that were in inventory. The purpose of these memory additions was to increase the computing resources of the ESXi hosts running the blade servers, such that the ECHO/CMR Development Virtual Environments could be migrated to those ESXi hosts.

A detailed report of activities completed under this task can found in the Task 05 Final Task Report (EED2-FTR-005), dated 10/31/2016.

Task 06 – Sentinel Gateway

Raytheon designed and implemented a robust, production-quality NASA Sentinel Gateway (NSG) Release 1.0 system and deployed it into the operations environment in January 2016, effectively retiring the NSG prototype system that was being used for operations support. When the European Space Agency (ESA) International Access Hub was made available in early January 2016, Raytheon immediately worked with NetOps on transitioning the NSG system to ingest data from the newly available data hub which provides dedicated, high-bandwidth data access. This effort resulted in an increase of over three times its previous daily average ingest throughput and scaled up the system capacity to support additional Sentinel missions and Distributed Active Archive Center (DAAC) client systems.

Furthermore, as part of NSG Release 2.0 development effort, Raytheon implemented additional features and capabilities to concurrently ingest data products from multiple Sentinel missions and distribute them to multiple DAACs. Through an extensive, end-to-end, sustained testing, Raytheon verified NSG capabilities to concurrently ingest Sentinel-1A, 1B, and 3A data products and distribute them to multiple DAAC systems including Alaska Satellite Facility (ASF), Level 1 and Atmosphere Archive and Distribution System (LAADS), Ocean Biology DAAC (OB.DAAC), and Physical Oceanography DAAC (PO.DAAC). An operational readiness review (ORR) for NSG Release 2.0 was conducted on September 26, 2016, and the system was subsequently deployed to operations.

A detailed report of activities completed under this task can found in the Task 06 Final Task Report (EED2-FTR-006), dated 10/31/2016.

Task 07 – CEOS WGISS Integrated Catalog (CWIC)

Under this task, Raytheon accomplished the following:

- Deployment of OpenSearch Validation as a service, allowing clients to test their OpenSearch implementations programmatically.
- Migration of the CMR OpenSearch API to the CMR environment in preparation for the ECHO retirement.
- Development of CWIC-based search capabilities into the Earthdata Search Client, allowing users to include CWIC collections in EDSC-based searches.

Raytheon coordinated with ESDIS and the CWIC team to obtain the CWIC Server source code from the CWIC server development team and conducted a thorough review of the code. Raytheon also designed, developed and deployed a replacement service for GCMD's collection-level Catalog Services for the Web (CSW), and replaced GCMD's collection-level OpenSearch API with the existing CMR OpenSearch API. Raytheon provided an OGC-compliant CMR CSW in the production environment during the week of August 3, 2016.

Raytheon updated the CWICSmart application to use the CMR OpenSearch API as default rather than the GCMD OpenSearch API prior to its retirement. Raytheon also applied security patches as necessary to CMR, CSW, CMR OpenSearch, CWICSmart, and CWICStart. All patches were applied to SIT, UAT and PROD environments within twenty-four hours of notification. Finally, Raytheon attended the ESDWG 2016 and ESIP Summer 2016 conferences to present sessions and discuss issues relating to CSW and OpenSearch in general and the applications and services CMR supplies in this realm in particular.

A detailed report of activities completed under this task can found in the Task 07 Final Task Report (EED2-FTR-007), dated 10/31/2016.

Task 08 – Earth Observation Data Interoperability

Under Task 8, Raytheon completed the fourth phase of a multi-phase effort directed at integrating innovation by improving interoperability and performance of EOSDIS data sets and services. Raytheon focused on promoting the Data Access Protocol (DAP) as a standard response for OGC's WCS 2.0 web API/standard, winning selection to participate in OGC's Testbed 12 initiative, raising user awareness of recent OPeNDAP Hyrax data server performance improvements, and performing sustaining engineering on the server. In support of OGC's Testbed-12 project, Raytheon worked with the OGC WCS and Coverages Domain Working Groups (DWGs) to determine what will be needed for DAP to become a recognized 'Encoding' for WCS 2.x.

Raytheon identified a multi-phase approach that began with making DAP a standard 'Response Encoding' for WCS 2.x and worked with the OGC Web Coverages Service (WCS) Standards Working Group and Coverages Domain Working Group to determine what process to follow.

OPeNDAP's primary roles are to evaluate the Web Coverage Processing Service (WCPS) and the Earth Observation profile of WCS 2.0 relative to providing access to 3D and 4D data (also referred to as 2D+Time and 3D+Time), completely new capabilities for WCS 2.0. To enhance the utility of the Hyrax server framework within NASA, Raytheon began a concerted effort to inform and educate NASA personnel about DAP, Hyrax and OPeNDAP – three distinct entities (protocol, software and organization).

Raytheon provided technical support to NASA for OPeNDAP software that included problem analyses, bug fixes, and assistance to Hyrax users at the DAACs. Raytheon also released Hyrax 1.12.2, 1.13, and 1.13.1 with corresponding documentation.

The primary goal of the Task 8 Metadata Improvement effort was to apply BEDI metadata evaluation tools developed earlier to metadata collections in the Common Metadata Repository and Unified Metadata Model recommendations. This facilitates understanding of metadata requirements and dialects among the ESDIS Earth Data Community and advances the information that can be gleaned from these tools to assess, measure, and improve existing and new earth science metadata. Raytheon evaluated over 16,000 CMR metadata records for completeness with respect to the UMM-Collection Profile. Raytheon also analyzed over 8000 CMR granule metadata records in ISO19115 and ECHO metadata dialects from the NASA Data Centers.

A detailed report of activities completed under this task can found in the Task 08 Final Task Report (EED2-FTR-008), dated 10/31/2016.

Task 09 – Next Generation Application Platform

Under Task 9, Raytheon conducted planning, estimation, and stand-up meetings for the development and infrastructure efforts. The team also introduced the Scaled Agile Frameworks (SAFe): Weighted Shortest Job First concept as a means of prioritizing development features. Raytheon worked to develop a prototype Cloud environment within the NASA CIO's AWS MCE. Raytheon also implemented a new feature into the build and deployment process that checks an application's compliance to the NASA standards by performing checks on the STRAW database.

Raytheon received approval of the Authority to Operate (ATO) paperwork for NGAP, incorporated NGAP into the EED-2 Configuration Management Plan, developed process documentation, defined an on-boarding process, and updated the Operating Agreement between ESDIS and Ames Research Center (NASA/ARC) to reflect the latest changes with NGAP.

Under Task 9 Modification 1, Raytheon conducted the GIBS Study, which presented three solutions for GIBS: "Fork-lifting" GIBS into the Cloud, Minor GIBS changes, and a Cloud native solution, with the team recommending the third option. The team completed the ASF Web Object Store integration effort to ensure that the GP-MCE network was modified so that traffic could flow between their cloud and on premise services. Raytheon also evolved NGAP to support a new IaaS solution that aligns with the WOS application architecture and ASFs needs on NGAP.

A detailed report of activities completed under this task can found in the Task 09 Final Task Report (EED2-FTR-009), dated 10/31/2016.

Task 21 – HDF Activities

The HDF Helpdesk team assisted with release testing, providing HDF developers with insight regarding issues that could potentially affect the community and allowing the team to gain knowledge regarding new features and open issues in each release. The Helpdesk team maintained the documentation and updated the web pages, including sample HDF4 and HDF5 files and example programs.

On Task 21, The HDF Group provided various HDF support to GES-DISC, EED-2, LP DAAC and MEaSUREs teams. For example, the team finished implementing an HDF5 OPeNDAP feature to improve the metadata retrieval performance by caching the OPeNDAP Hyrax DAS metadata in disk, in addition to caching the Hyrax metadata in memory. A major effort was made in testing the

new version of IDL and updating the IDL OPeNDAP-related example pages to address new requirements from NASA data centers to use URS for accessing data.

The HDF Group updated and maintained the HDF-EOS website, including hosting and participating on the HDF-EOS forum, adding links and information regarding new tools and software, and adding comprehensive example contents for data products that user requested. Regular newsletters were published and sent by email to keep users informed of software releases and other information regarding HDF technologies.

The HDF Group continued working closely with OPeNDAP, Inc. by providing software to access data products stored in the HDF4 and HDF5 file formats, new features to HDF5 OPeNDAP handler to improve performance, and by assisting with reporting and fixing bugs in the Hyrax software.

The HDF Group delivered Product Designer Tool version 1.6.0, Product Designer Server version 1.0.0, HDF5 versions 1.8.18, 1.8.19, and 1.10.1, HDFView 2.14 and 3.0-beta, and various patches. The HDF Group performed software regression testing using cloud services, to more economically and easily support additional platforms and to reduce maintenance cost and effort. These testing activities provided value by continuously ensuring software quality and by using new technologies and processes to improve effectiveness and efficiency.

The primary goal of The ISO Standardization task was to provide expertise in ISO Technical Committee 211 Standards and other standards and conventions that support discovery, use, understanding, sharing, and preservation of observations, data, and model results for ESDIS. The HDF Team has served as the lead of the 19115-3 (Metadata Fundamentals XML Schema), and 19157-2 (Data Quality Metadata Schema) project teams and the ISO TC211 XML Management Group.

Progress continued on the revision of ISO 19115-2 Standard that includes all extensions developed by the ESDIS Metadata Evolution for NASA Data Systems (MENDS). These extensions included the capability to add ECHO Additional Attributes to ISO metadata records in a way that is consistent with the International Standard. The revision also included a standard for describing instrumentation events and changes that might affect the scientific value or temporal consistency of datasets.

Lastly, Raytheon worked with the ESDSWG Airborne Metadata group to develop a model for describing metadata for parameters in ISO 19115-1. This model demonstrated how metadata components required for describing spatial representations, data quality, and parameter properties can be connected in metadata records to meet the requirements identified by the Airborne Metadata group.

A detailed report of activities completed under this task can found in the Task 21 Final Task Report (EED2-FTR-021), dated 10/31/2017.

Task 22 – SDPS Sustaining

Under this task, Raytheon continued the program management, program control, reporting / reviews, supply chain management, and security management conducted under Task 2. These endeavors included supporting the ESDIS goals of cloud feasibility and supporting the ExCEL project. During this contract year, Raytheon conducted five Program Increment Planning meetings (PI3 through PI7).

Raytheon produced four Releases of the SDPS software (8.4.2.1, 8.4.3, 8.5 and 9.0). Raytheon transitioned the SDPS baseline to PostgreSQL 9.6.2 client-side beginning with Release 8.5, while the server-side transition was accomplished during development of Release 9.0. Raytheon also provided extensive support to subsetting, reformatting, and reprojecting of Earth Science data. Raytheon continued the development of Service Gateway components. This work included adding support for WCS, version 1.0.0 - 2.0.1 to EGI for ArcGIS/QGIS, gdal_translate, owslib.py, and other clients; completion of the EOSDIS Services Architecture Trade Study comparing WCS versions, EGI and OPeNDAP, development of programmatic access capability, and integration with CMR search.

Raytheon supported the SMAP, VIIRS, ASTER, ICEBridge, MODIS, MISR, and SAGE III/ISS missions and instruments by delivering new and updated ESDTs. Raytheon improved the HEG tool to support MOPITT and VIIRS level 2 and 3 products. Raytheon also released HEG version 2.14, which supports HEG services on the Linux32, Linux64, Macintosh, and Windows 7, 8, and 10 platforms.

Raytheon generated 48 hardware / software procurements. The team received all materials that were approved for shipment to ECS DAACs without any discrepancies and delays, and the receiving NASA Site Property Custodians confirmed receipt of all deliveries and reported no impact to their day-to-day tasking.

For the DAAC capacity increase and technology refresh, Raytheon delivered storage expansion hardware for the DAACs to add capacity for 2017 Ingest forward processing at ASDC, NSIDC, and LPDAAC, migrated all PVC StorNext managed file systems from CX-4 array to VNX5800 in preparation for retirement of CX-4 array while provisioning additional space to grow OPS file systems, and delivered EMC Operating Environment upgrade to provide compatibility for recent versions of Java and security enhancements for the VNX arrays.

Raytheon uninstalled and removed 2 STK Powderhorn tape library silos from Langley Research Center in Hampton Virginia, provided additional storage capacity required by the GWELD mission at LP DAAC for data ingest, archive, and distribution, and procured the material needed for FY2018 Technology Refresh and Capacity expansion.

A detailed report of activities completed under this task can found in the Task 22 Final Task Report (EED2-FTR-022), dated 10/30/2017.

Task 23 – Earthdata

Under this task, Raytheon developed, evolved, and sustained software for the following subsystems (in addition to those sustained under Task 03):

- Earthdata TopHat.
- Earthdata Status Application.
- Earthdata Enterprise Configuration System (EECS).
- Earthdata Developer’s website (developer.ngap.earthdata.nasa.gov).

Raytheon expanded the concept of the Web Infrastructure team by rolling out the major releases to Kayako, Puppet, Bamboo and the Google Search Applications. Raytheon open-sourced the Conduit application, and made significant changes to the Developer Portal, including the formatting of search results. Raytheon also collaborated with ESDIS and NetOPS to implement the new Two-Factor Authentication solution to the Earthdata System Components.

Raytheon enhanced and maintained the deployment stack suite of tools and used the EED-2 SAFe / agile processes to make enhancements to the Development Portal, Status Application, TopHat, and the Feedback Module. Highlights of the major enhancements achieved were the addition of NAMS authentication for Conduit, the Status application, and the DevPortal; the additions of GIBS, EDSC, and the Earthdata Login documents to the Earthdata Developers Portal.

Raytheon held the Earthdata Login Technical Interchange meeting, to coincide with the EED-2 SAFe Program Increment 6 Planning meeting and dealt with identifying and documenting issues with the system. Raytheon also continued to implement several DAAC customer requests to assist with integration to Earthdata Login, such as the development of Group Management functionality and API support to update user groups and retrieve group info with user profiles, additional user fields to support Sentinel Data, auto authorization of ESDIS applications without End User Agreements, modifications to group functionality to support, CMR, MERIS, Document Builder, and ED Drive; and API changes to support capturing the NAMS AUID in the User Profiles. Raytheon also completed 508 compliance assessments on Conduit and on the Status application.

A detailed report of activities completed under this task can found in the Task 23 Final Task Report (EED2-FTR-023), dated 10/30/2017.

Task 24 – GIBS Prototype

In support of the joint effort between ESDIS and MSFC, Raytheon worked closely with the MSFC contractor to identify components for prime reuse between GiTC (GIBS in the Cloud) and Cumulus. Raytheon worked cooperatively with the JPL development and the SES operations contractors to successfully migrate GIBS and Cumulus code baselines to NGAP.

Raytheon developed and continues to support a pseudo-operational prototype of the GIBS system operating in an Amazon Web Services (AWS) environment and integrating, as appropriate, code developed by generic ingest and archive prototype team as well as GIBS-specific software.

A detailed report of activities completed under this task can found in the Task 24 Final Task Report (EED2-FTR-024), dated 10/30/2017.

Task 25 – Common Metadata Repository (CMR)

Under this task, Raytheon successfully stood up the Software Integration Test (SIT, User Acceptance Test (UAT), Workload, and Operational environments for CMR on the NGAP Cloud Platform. The final cutover to the operational system occurred successfully on 4/19/17 and was completed in less than half of the advertised down-time window due to detailed cutover planning which accounted for every detail required to perform the cutover. Since the cutover, the CMR has achieved its highest performance to date regarding collection and granule query response times.

In order to support NASA's focus on assigning a DOI per each collection, Raytheon elevated the DOI element to a prominent location in the Unified Metadata Model and added it to the ECHO10 metadata schema so that DOIs can easily be ingested into the CMR.

Given the broad nature of the initial ideas for a Unified Metadata Model for Documents (UMM-D), the EED-2 team facilitated a specification workshop with all ESDIS stakeholders to understand the key use cases and develop an approach for UMM-D. In order to help Reverb users become familiar with EDSC, Raytheon used a proven Usability Testing approach to assess users attempting to do the same task on Reverb and on EDSC. Raytheon also completed two different marketing pamphlets for use at User Working Groups to highlight Reverb's retirement and provide information on Earthdata Search Client.

Raytheon orchestrated curation activities with GHRC's Analysis and Review of CMR (ARC) team and the Global Change Master Directory (GCMD) team. The initial MMT Bulk Update feature was also completed during execution of Task 25, which allows providers to update the Science Keywords on multiple collections simultaneously, reducing the effort required to fix invalid metadata. Raytheon also continued its efforts to improve relevancy in the CMR and worked to allow external systems to more easily discover NASA data.

Since the CMR has proven its stability over the past year, Raytheon adjusted its focus to migrating any remaining functionality from the legacy ECHO and PUMP systems to the CMR so that associated legacy hardware can be decommissioned prior to the hardware reaching end-of-life.

Raytheon team deployed numerous software updates for UMM, CMR/MMT/EDSC and ECHO/Reverb/PUMP for COTS products such as Red Hat Enterprise Linux, Oracle Linux, Splunk, Elastic Search, vSphere, Java, and VMWare Backup Appliances. This effort included monthly OS updates for all CMR/ECHO servers, and security fixes and maintenance patches for 3 VMWare vCenter Server Appliances. Raytheon also provided preventive and corrective maintenance and engineering support for all UMM, CMR/MMT/EDSC and Reverb/PUMP computing equipment at the GSFC, Building 32.

Raytheon deployed ninety-four live releases for CMR, Earthdata Search, ECHO and the MMT to Operations, with no degraded service in the production environment. All CMR and ECHO services maintained an availability of greater than 99% except for Earthdata Search, which maintained an availability of 88%. Several issues arose with the running of Earthdata Search background tasks for caching metadata. During these issues, health checks of Earthdata Search failed, correctly, even though the application was available.

A detailed report of activities completed under this task can be found in the Task 25 Final Task Report (EED2-FTR-025), dated 10/30/2017.

Task 26 – Sentinel Gateway

Raytheon continued developing the NSG system using the agile development approach. The NSG operations support was expanded to include one new Sentinel mission - Sentinel-3A starting October 21, 2016, and one additional client system - SMAP SDS, starting June 9, 2017. By the end of Task 26, the NSG operation routinely ingested data products from three Sentinel missions (Sentinel-1A, 1B, and 3A) and distributing them to four client systems/DAACs (Alaska Satellite Facility (ASF), Level 1 and Atmosphere Archive and Distribution System (LAADS), Ocean Biology DAAC (OB.DAAC), and SMAP SDS).

Starting in late September 2016, soon after ESA started publishing Sentinel-1B data products on their data hub, the NSG system began experiencing degradation in ingest throughput manifested by a significant number of intermittent HTTP 502/503 errors and premature transfer cutoffs when acquiring Sentinel data products from the ESA International access hub. To help understand and resolve the issues, Raytheon worked with the NASA NetOps team to monitor network throughput between the NSG and ESA data hubs; set up Nagios system monitoring tool to monitor the health of the NSG application services and the https web service end points at ESA data hubs; collected and provided error statistics to ESA via the ESDIS task monitor to help ESA diagnose the throughput issues on ESA data hub end. As the result, the data transfer rate had improved significantly starting around mid-December 2016.

Due to these ingest throughput issues, the ASF DAAC was unable to acquire Sentinel-1A and 1B data products at the desired data rates during September to December 2016 time period. This had resulted in a backlog of over 20,000 granules to be backfilled. Therefore, Raytheon set up the NSG system to re-acquire missing data products in batches, in order of priority requested by ASF.

In preparation for Sentinel-5P support, Raytheon coordinated with the GES DISC personnel and successfully set up the data distribution interface between NSG and the GES DISC system for distribution of Sentinel-5P data products. Raytheon collected Sentinel-5P data product information including file naming convention and various product types, based on information and documents published on the ESA Sentinel websites. They also downloaded sample Sentinel-5P data products made available by ESA and used them as the basis for enhancing the ESA data hub simulator to support software development and testing. Raytheon provided updates to the NSG-DAAC ICD by incorporating Sentinel-5P related information including projected daily data volumes and various product types to be distributed to the GES DISC.

Raytheon generated a set of simulated Sentinel-3B data products by cloning Sentinel-3A data products. The simulated data were used to test and verify the core ingest and distribution functionalities, allowing the Raytheon to complete the implementation on 9/15/17. Raytheon developed a product filtering capability that allows NSG application to filter out certain Sentinel 3A data products based on the Class ID attributes of the data granule when distributing them to a DAAC.

Raytheon onboarded a new client system, SMAP SDS, to acquire Sentinel-1A and 1B data products from the NSG system. During SMAP SDS onboarding, Raytheon also developed a capability to ingest Reprocessed/Replaced Sentinel-1A and 1B Data Products.

Raytheon enhanced the ESA data hub simulator to be able to generate a continuous data stream for each Sentinel mission using a set of sample data products as the seed. The capability played a crucial role in performing end-to-end testing to verify various NSG enhancements implemented during the task year including Sentinel-5P and 3B functionalities.

To provide a standard way for reconciling inventories between the DAACs and the NSG, Raytheon proposed an inventory reconciliation approach and reviewed it with ESDIS task monitor and the DAACs, including ASF, LAADS, OB.DAAC, and Physical Oceanography DAAC (PO.DAAC). The approach is documented in the updated NSG-DAAC Interface Control Document (ICD) which was delivered to ESDIS on September 26, 2017.

Raytheon provided system administration and maintenance support for all NSG environments by performing regularly scheduled Planned Maintenance (PM) activities on a monthly basis or as needed to ensure that the NSG system components are kept secure and up to date with latest operating system and security patches. Raytheon submitted STRAW registrations for two web-based applications – Nagios Web Application for system monitoring, and InsightIQ for Isilon storage cluster monitoring, deployed in UAT and the OPS environments. To fully utilize the high availability features provided by the EMC Isilon storage cluster, Raytheon implemented Domain Name System (DNS) Zone Delegation for the storage cluster in the NSG operations environment.

A detailed report of activities completed under this task can found in the Task 26 Final Task Report (EED2-FTR-026), dated 10/30/2017.

Task 27 – CEOS WGISS Integrated Catalog (CWIC) for EOSDIS

Under Task 27, Raytheon open-sourced both the CMR Open Search and CSW projects on NASA GitHub. Raytheon also migrated these services from on-premises hardware to the cloud leveraged NGAP (NASA-compliant General Application Platform) and began migrating CWICSmart (CWIC OpenSearch) and CWICStart (CWIC CSW) to the cloud.

Raytheon provided additional functionality to CMR CSW and CMR OpenSearch, including augmenting metadata with the “isEOSDIS” property and providing a Provider ID search constraint. Raytheon also augmented CMR OpenSearch functionality to filter results by ESDIS and CEOS collections. Finally, Raytheon continued to build on the functionality and usability of CWICSmart by adding validation rules for the CEOS OpenSearch Developers Guide 2.0D3 and Best Practices V1.1.1.

A detailed report of activities completed under this task can found in the Task 27 Final Task Report (EED2-FTR-027), dated 10/30/2017.

Task 28 – Earth Observation Data Interoperability

Under Task 28, Raytheon conducted a trade study that identified three high performance integrated solutions for storing and retrieving NASA HDF5 and netCDF4 data in Amazon Web Services (AWS) Simple Storage Service (S3) environment developed a cost model for each data storage solutions. Raytheon recommended that ESDIS develop a hybrid architecture that combines two of these architectures to provide the best performance for a wide range of access scenarios.

For the Web-Accessible APIs effort, Raytheon wrote write a step-by-step guide for users and clients accessing data through the OPeNDAP API. Raytheon reworked data access examples available at <http://hdfeos.org> to add information about ESDIS-specific OPeNDAP access,

Raytheon continued the community involvement efforts performed under Task 08 and started the ESDS Dataset Interoperability Working Group (DIWG) best practice recommendation effort.

For Metadata Improvement, Raytheon applied and enhanced metadata evaluation tools for data providers beyond what was developed in earlier phases. This facilitates comparison of existing metadata content in several dialects with respect to requirements used by ESDIS and other members of the U.S. Earth Data Community and advances the information that can be gleaned from these tools to assess, measure, and improve existing and new Earth Science metadata.

Raytheon responded to reviews of EED2-TP-014, Unified Metadata Model – Collection Recommendation Report for NASA DAACs and added appendices addressing Dialect and Metadata Evolution in response to suggestions received at ESIP and elsewhere. In order to provide guidance for NASA metadata managers with respect to the NASA Mission Metadata requirements, Raytheon updated the NASA Earthdata Wiki pages on ISO metadata related to those requirements and added intermediate pages that provide descriptive material with respect to each of the Mission Requirements.

Raytheon extended Metadata Collection Evaluation and Comparison to include the two largest groups of metadata in the CMR: records from the International Directory Network (IDN) and from SciOps (formerly the GCMD). These records make up the majority of the CMR, originate from multiple U.S. and International organizations, and were primarily developed in the DIF dialect. Raytheon analyzed eight IDN collections and twenty-five SciOps collections that included more than one hundred records and compared these collections to those from the ESDIS DAACs.

This analysis of CMR content provided by NASA DAACs provided our first opportunity to compare record content from two time periods. Raytheon developed graphical comparisons tools that use bubble charts to compare the percent of records during 2016 and 2017 that include content for some documentation element. This approach makes it easy to identify elements that have increased or decreased in completeness over time, identifying new content and improvements in the translations from the CMR to ISO.

For OPeNDAP Evolution and Sustaining Engineering, Raytheon provided technical support that assists in deploying DAP capabilities, assists in testing or interoperability exercises NASA conducts or participates in that includes Hyrax (including Testbed 12), promotes better understanding of client needs and use of Hyrax capabilities, and increases sustaining engineering for Hyrax (including making WCS service available). Most notably, Raytheon's OPeNDAP team completed OGC Testbed 12 work on a WCS 2 service that implements the Earth Observation Profile for WCS (EO WCS) that NASA and OGC developed previously. The OPeNDAP team also provided problem analyses, bug fixes and requested features, two new versions of the Hyrax OPeNDAP server, and assistance to Hyrax users at DAACs, and developed and published a WCS 2 server implementation that NASA can deploy as a component that is part of Hyrax. Finally, the OPeNDAP team developed an automated data ingest module specifically suited to the metadata standards that NASA employs.

A detailed report of activities completed under this task can found in the Task 28 Final Task Report (EED2-FTR-028), dated 10/30/2017.

Task 29 – Next Generation Application Platform

Under Task 29, Raytheon continued to partner with the NASA Computing Services Service Office (CSSO) to develop a Cloud Solution for ESDIS and delivered NGAP 1.5 and the new version for the NGAP Sandbox. Raytheon migrated the EED-2 Earthdata Search Client and the Earthdata Developer Portal to the NGAP PaaS environment.

Raytheon worked closely with the CSSO to ensure that the features and services (AWS products) required by NGAP were implemented and tested in a timely manner and improved the billing reports through the use of NGAP specific tagging on the AWS services. Raytheon also worked with the NASA CSSO and the ESDIS SOC to improve the security process around NGAP. On the cost model side, Raytheon developed a series of scripts executed by the AWS Lambda service that monitored and enforced appropriate tagging on AWS services running on NGAP.

Raytheon completed the integration with Splunk and CloudWatch in order to improve the logging, monitoring and reporting components of NGAP. Raytheon also began developing an NGAP/CSSO call tree for production issues.

To improve the end-user experience and to ensure the success of the ExCEL project, Raytheon completed the development of the MVP version of the NGAP Sandbox, using Docker containers running on EC2 instances. This innovative effort included converting the NGAP platform as a service (PaaS) to a container-based solution.

A detailed report of activities completed under this task can found in the Task 29 Final Task Report (EED2-FTR-029), dated 10/30/2017.

Task 30 – Earthdata Search

Under Task 30, Raytheon shut down Reverb on January 2, 2018, following a “user race” between the Earthdata Search Client (EDSC) and Reverb that proved that the EDSC outperformed Reverb

and met the needs of Reverb users. Raytheon provided updates to the EDSC that allowed the DAACs to tag collections that caused bottlenecks and alert users about a potential delay.

Raytheon collaborated with ASDC and PO.DAAC to explore ways to augment the EDSC to further assist their users and provided customized training that highlighted specific features to assist each DAAC.

Raytheon released EDSC versions 1.51 through 1.74 on a regular bi-weekly schedule. Raytheon also completed several configuration refinements of the EDSC in the new NGAP 1.1 environment to enhance stability and performance. Raytheon also monitored the EDSC codebase, the Access tool (for 508 compliance), and the operational systems for security vulnerabilities.

A detailed report of activities completed under this task can be found in the Task 30 Final Task Report (EED2-FTR-030), dated 10/31/2018.

Task 31 – Enabling EOSDIS Data Usage

The HDF Helpdesk team continued to provide technical support to the user community and maintained sample files and other documentation. The HDF team also supported GES DISC, LP DAAC and NSIDC on the use of OPeNDAP Hyrax services and other tools to access HDF4 and HDF5 products distributed by the DAACs. The HDF team updated and maintained the HDF-EOS website (<https://hdfeos.org>), including hosting and participating in the HDF-EOS forum, adding information regarding new tools and software, and comprehensive example contents for data products requested by the users. For NCAR Command Language (NCL), verbose scripts were shortened as NCL has improved in releasing resources. Starting July 2018, the HDF team began sending out monthly newsletters to keep the DAACs informed of the new supported products and updates performed at the HDF-EOS Website.

The HDF team worked with tool builders and vendors that provided software to access ESDIS data. Raytheon continued working closely with OPeNDAP to provide software to access data products stored in the HDF4 and HDF5 file formats and assist with reporting and fixing bugs in the Hyrax software. The team also continued working with MathWorks, providers of MATLAB, to resolve compatibility issues between MATLAB versions built with the HDF5 1.8 and HDF5 1.10 releases.

The HDF team delivered the following software releases:

- HDF Product Designer 1.6.0 and 1.6.1.
- HDF5 1.8.20, 1.8.21, 1.10.2 and 1.10.3.
- HDF 4.2.14.
- HDFView 3.0.
- HDF4 to HDF5 Conversion Toolkit 2.2.4.
- HDF5 OPeNDAP Handler.

The HDF team continued to represent ESDIS by leading the 19115-3 (Metadata Fundamentals XML Schema), 19157-2 (Data Quality Metadata Schema), and 19139-1 (XML Encoding) project teams and the ISO TC211 XML Management Group.

The revision of the ISO 19115-2 Standard was finalized, including all extensions developed by the ESDIS Metadata Evolution for NASA Data Systems (MENDS). These extensions include the capability to add ECHO Additional Attributes to ISO metadata records in a way that is consistent

with the International Standard. The revision also includes a standard for describing instrumentation events and changes that might affect the scientific value or temporal consistency of datasets.

The HDF Team also worked with the Landsat team to develop granule metadata for the Landsat-9 using ISO standards. These metadata are currently distributed in separate files written in Object Description Language (ODL).

In support of the Architecture #2 effort, Raytheon added several important features to the Hyrax server to implement Architecture #2 and integrate with the CMR API to support the virtual directory capability. Raytheon also developed cost models for operating Web Accessible APIs in the Cloud (WAAC) and for Architecture #2.

Raytheon conducted a series of extensive tests to assess the performance of Hyrax in the Cloud under various data access scenarios, discovering that performance was improved when storing metadata objects separately from data, adapting the data transfer and processing algorithm to exploit parallelism, and ensuring that data transfers employed connection reuse.

A detailed report of activities completed under this task can be found in the Task 31 Final Task Report (EED2-FTR-031), dated 10/31/2018.

Task 32 – SDPS Sustaining

Under this task, Raytheon continued the program management, program control, reporting / reviews, supply chain management, and security management conducted under Task 22. Given the emphasis in developing requirements in tasks that largely are supported by the Scaled Agile Framework (SAFe), the organization was modified to clarify leadership roles. The traditional task lead role was redefined to be primarily cost account management, while the execution of the task statements of work would be managed by the train leadership. In addition, a Mission Engineer role was identified to provide Software Systems Engineering support as the point of contact for program mission support to the customer in identifying, defining and promulgating requirements across the EED-2 program. NISAR and SWOT are the first missions to be planned and managed in this fashion, with the EED-2 Mission Engineer as the lead of the feature team.

Raytheon assisted ESDIS with developing a Cost Management framework for the Earthdata Cloud development effort, which included the development of a cost estimation spreadsheet. Raytheon piloted these spreadsheets with PO.DAAC and ASF and began gathering the data necessary to help optimize each account's actual expenditures. Raytheon also worked closely with the CloudChecker and CloudTamer teams to ensure consistent reporting across the two cost management tools. The work has resulted in changes to the CloudChecker billing reports, the implementation of budget/spend alert thresholds, and budget enhancements to the CloudTamer application.

Raytheon produced four releases of the SDPS software (9.1, 9.2, 9.3 and 9.4). These releases updated SMAP field names and provided latitude and longitude associations, HEG, and Data Access services for certain VIIRS data products, and subsetting, reprojection, and format support for VIIRS product VNP13A1. These releases also supported specific ICESat-2 products by providing Shapefile, ASCII, NetCDF3, and NetCDF-4 formatting, special subsetting support for ICESat-2 ATL08 photon data, and spatial and temporal subsetting for ICESat-2 ATL10 Sea Ice Freeboard products. Finally, Release 9.3 added Earthdata Login (URS) authentication to ESI Result (ESIR) REST web service.

Raytheon routinely delivered COTS software updates and maintained SDPS computing and networking equipment at all three DAAC sites and the Riverdale facility.

Raytheon supported the ICESat-2, SMAP, MISR, and SAGE III/ISS missions and instruments by delivering new and updated ESDTs. Raytheon improved the HEG tool to support VIIRS level 3 products. Raytheon also modified Stand-Alone HEG to add mosaicking support of VIIRS and SRTM products in order to provide the end users with the ability to work with data over their area of interest instead of on arbitrary granule boundaries.

Raytheon provided support to the ASDC in the containment and recovery following a cooling system failure in the main server room, on October 30, 2017. Due to the extreme temperatures and risk to health and safety, the power to the entire server room was shut down, resulting in all systems being unsystematically powered off. In order to get the ECS back online, Raytheon worked with ASDC to carefully rebuild all of the disks that were impacted.

For the DAAC capacity increase and technology refresh, Raytheon replaced six data management workstations at NSIDC and ASDC. Raytheon also replaced four Linux servers, five work group servers / Sun Ray hosts, and three server blades. Raytheon provided a 500 TB capacity expansion to LP DAAC for GWELD data collections, expanded the StorNext archive and provided a storage array for NSIDC, and delivered a 1.2 PB usable capacity storage expansion to ASDC for their 2018 Forward Processing campaign.

A detailed report of activities completed under this task can found in the Task 32 Final Task Report (EED2-FTR-032), dated 10/31/2018.

Task 33 – Earthdata

Under this task, Raytheon continued developing, evolving, and sustaining software for the subsystems sustained under Task 23.

Raytheon expanded Web Infrastructure support by rolling out the major releases to Jira, Bamboo, Bitbucket, and Jama. Raytheon supported the following shared functions across the web infrastructure: UI / UX, Continuous Deployment, System Administration, Service Integration, and Operations. Raytheon also completed the open-source process for the Status App. Raytheon enhanced and maintained the deployment stack suite of tools and migrated GCMD legacy applications and the CMR-Dashboard tool into the CI / CD build and deployment processes. For Earthdata Login, Raytheon developed the capability to re-authorize End User License Agreements (EULAs).

Raytheon's UI / UX team led an NGAP Onboarding Workshop and conducted upgrades to the Earthdata website. The team also led the Data Experiences feature effort, which explored what the user experience would look like when the majority of data were accessed from the cloud.

Raytheon provided support and planning for the Earthdata User Interface Library (EUI) and completed roadmap planning and user analytics studies in preparation for EUI 2.0. Raytheon released EUI versions 1.1.4 and 1.1.5, which supported an improved feature grid component.

In 2018, NASA celebrated Earth Day by highlighting the Earthdata effort, and Raytheon supported a considerable increased load (85%) on the Earthdata website and WorldView during this time. As a result, the Earthdata website earned a spot on mashable.com's "best websites to keep tabs on Planet Earth." Raytheon also continued to provide consistently high availability for Earthdata Login, with uptime metrics of 99.89% for URS4 and 99.97% for URS3. Raytheon helped

Earthdata Login implementers at various data centers integrate their applications with the Earthdata Login4 application, providing one-on-one support as needed.

Raytheon continued to utilize Puppet to manage security updates and increased the security profile of Earthdata by implementing password aging policies across all hosts for specific privileged users in compliance with NASA security practices.

A detailed report of activities completed under this task can found in the Task 33 Final Task Report (EED2-FTR-033), dated 10/31/2018.

Task 34 – GIBS in the Cloud and Cumulus Development and Operations

Raytheon designed and developed a prototype of GIBS in the Cloud (GitC) that uses only cloud-based services, and worked with ESDIS, JPL, and the SES Contractor to define and develop a minimally viable GitC product. Raytheon enhanced the Cloud-based Imagery Servicing and Ingest pipeline for processing data and generating Meta Raster Format (MRF) onto the AWS S3, and implemented OnEarth 2.0, which capitalizes on AWS technologies. Raytheon worked with the larger GIBS team (Cumulus, NGAP, and NASA Security teams, and USGS representatives) to enable GitC to perform end-to-end processing of AST-L1T data with display in GloViz.

Raytheon led the Cumulus team in technical architecture, systems engineering in alignment with SWOT deliverables, and technical execution. Raytheon worked with ASF's GRFN team identify solutions to common challenges and avoid duplication of effort. Raytheon collaborated with ESDIS, MSFC, and the DAACs to integrate Cumulus into DAAC accounts hosted on NGAP and develop a common cost model and estimator for DAACs to use when calculating the cost of running Cumulus against their collections. Raytheon worked closely with PO.DAAC to identify Cumulus requirements for each SWOT milestone and prioritize work accordingly.

For Cloud Based Metrics, Raytheon conducted a trade study among fourteen log aggregation and business intelligence tools and prototyped the recommended solution to demonstrate how the ElasticSearch, LogStash and Kibana (ELK) stack and Looker could provide Cumulus operators and analysts with insightful information based on log data.

A detailed report of activities completed under this task can found in the Task 34 Final Task Report (EED2-FTR-034), dated 10/31/2018.

Task 35 – Common Metadata Repository Evolution

Under Task 35, Raytheon migrated remaining functionality from the legacy ECHO system to the CMR and other enterprise tools such as Earthdata Search Client. Raytheon developed an integration with the NASA Launchpad SSO system and added support for a dual login using either Launchpad or Earthdata Login to ensure uninterrupted service to the Metadata Management Tool (MMT) during migration. When the Raytheon established CMR in the NGAP test environment in order to test CMR's compatibility with the NGAP API.

Task 35 moved CMR Dashboard to the EED-2 Program, and Raytheon developed a migration plan to move the CMR Dashboard onto EED-2 infrastructure. Raytheon also deployed the CMR Dashboard in the EED-2 test and production environments and worked with the ARC team to ensure that no functionality was lost. Finally, Raytheon completed the open source and NASA GitHub requirements for CMR Dashboard.

Raytheon supported SWOT by creating a new UMM-G JSON schema, along with sample records consisting of UMM-G, ISO MENDS, and ISO SMAP, and by providing a mapping spreadsheet

that defines how the CMR will map elements between the different specifications. Raytheon supported the DAACs and international partners in curation of metadata records, including DIF 9, DIF 10, SERF, and UMM-S.

In order to make CMR holdings more easily accessible, Raytheon met with Google representatives to share the CMR's new site directory feature, allowing Google to crawl the CMR holdings more easily. Raytheon also added a new "sort by end date" and "sort by popularity" functionality to EDSC, helping users find relevant science data more easily.

Following an incident where OB_DAAC accidentally deleted their entire provider holdings from the CMR database and only had 1-day rolling backups on their database, Raytheon helped them re-ingest their missing data and requested that they reinstitute a 7-day rolling backup plan. Raytheon also performed a complete audit on all the other backup systems. Finally, Raytheon modified the code to prevent deletion of a provider if it still had collections in its inventory.

A detailed report of activities completed under this task can found in the Task 25 Final Task Report (EED2-FTR-035), dated 10/31/2018.

Task 36 – Sentinel Gateway

Under this task, Raytheon expanded the NSG to include a new Sentinel mission (Sentinel-5P) and the Goddard Earth Science Data and Information Services Center (GES DISC). In order to support Sentinel-5P data products, Raytheon obtained a set of early mission Sentinel-5P products and conducted end-to-end testing with GES DISC. Raytheon also used simulated Sentinel-5P data and real Sentinel S1A, S1B, and S3A data in order to verify the NSG's ability to support all missions simultaneously. Additionally, Raytheon obtained the necessary credentials to access the S5P Expert hub in order to acquire Sentinel-5P Calibration / Validation data products and provide them to the principal investigator scientist at GSFC for early review.

When the NSG experienced extended periods of low throughput in acquiring Sentinel-3A products from the ESA Sentinel-3A pre-operational data hub, Raytheon worked with ESA and determined that the issue was caused by ESA's system maintenance and software upgrade activities. In order to help mitigate the backlog, which had reached twelve days, Raytheon implemented a temporary prioritization scheme allowing near-real-time data products to be acquired and distributed ahead of standard products and reprocessed data products. Raytheon also configured the NSG's User Acceptance Test (UAT) environment to acquire reprocessed products on a low priority basis, freeing up bandwidth on the production environment for higher priority data products.

Raytheon coordinated with the NASA NetOps team to facilitate network connectivity between NSG and ESA's new Inthub2. Raytheon also deployed a redundant database configuration in the NSG Operations environment to provide enhanced NSG system availability. When the NSG primary database server failed, causing the PostgreSQL application to crash, Raytheon was alerted by the Nagios monitoring tool, and exercised the failover procedure promoting the hot standby database server as the primary server, avoiding NSG application failure and ensuring high availability.

A detailed report of activities completed under this task can found in the Task 36 Final Task Report (EED2-FTR-036), dated 10/31/2018.

Task 37 – CEOS WGISS Integrated Catalog (CWIC)

Under Task 37, Raytheon migrated OpenSearch-UI (previously known as CWICSmart) and CSW-UI (previously known as CWICStart) off of ECHO hardware onto the cloud, leveraging NGAP 1.1. Raytheon modified the OpenSearch client to be ESIP / CEOS compliant, providing OpenSearch practitioners with an example of how to produce their own clients.

Raytheon collaborated extensively with ESA in reviewing the CEOS OpenSearch Conformance Test Plan v 1.0.D4, resulting in a new version posted for comments in August 2018. Raytheon also worked with GSFC staff to move OpenSearch-UI and CSW-UI through the open sourcing process.

A detailed report of activities completed under this task can found in the Task 37 Final Task Report (EED2-FTR-037), dated 10/31/2018.

Task 38 – SAFe for ESDIS

Under Task 38, Raytheon expanded the single Scaled Agile Framework (SAFe) train to three trains: Ingest and Archive, Data Use, and Platform. This allowed ESDIS to manage numerous products, including those outside of the EED-2 Program, within a single SAFe program structure. Raytheon assigned staff from outside of the EED-2 Program to leadership roles within SAFe in order to increase visibility and collaboration.

Raytheon implemented recurring train meetings with train leadership and held specification workshops that were open to all train members. Raytheon also removed barriers to cross-contract teams, creating the Cumulus team (with EED-2 and DevSeed), GitC team (with EED-2 and JPL), and ATO Development team (with EED-2 and ESDIS Security).

Each team conducted “Scrum of Scrum” meetings twice each week to discuss the low-level status of progress against each task’s three-month plans. Each train worked according to the same Program Increments (PIs), which lasted approximately three months. The first three-train PI Planning Session was held in January 2018.

Raytheon and the external SAFe participants successfully executed three PIs (18.1, 18.2, and 18.3) during the Task 38 period of performance and completed the PI Planning session for PI 18.4.

Raytheon helped ESDIS develop and manage portfolio level EPICs, breaking each EPIC down into actionable features for the trains to execute against at the program level. This effort included planning the SWOT and NISAR missions.

A detailed report of activities completed under this task can found in the Task 38 Final Task Report (EED2-FTR-038), dated 10/31/2018.

Task 39 – NASA-Compliant General Application Platform

Under Task 39, Raytheon completed the buildout of the NGAP 2.0 account for the SWOT Mission initiative. This work included obtaining a new AWS account, inflating the account with the NGAP 2.0 scripts, linking the account to CloudTamer, and onboarding staff from JPL to manage the account.

Raytheon assisted the CIO team in executing the Memorandum of Understanding to manage the security policy for the NGAP Sandbox. The team also began the process of converting Sandbox accounts to the new 2.0 architecture.

Raytheon conducted a Cloud Billing Study, determining that the best way to manage costs is through the CloudTamer application. Raytheon also developed a cost estimation process that application teams would use to estimate budgets and ESDIS would use to approve budgets. Finally, Raytheon setup account billing notifications and linked the CloudTamer alerts with those from the billing system (CloudChecker). Raytheon worked with NASA EMCC, ESDIS Security, and CloudTamer to improve the security process around NGAP and achieve the ESDIS Cloud ATO in July of 2018.

The NGAP team provided operations support for the production NGAP clients (ASF, CMR, and EDSC), improving the stability of the environments and involving items such as automating the NGAP build process via the EED-2 CI/CD tool suite. The team conducted several on-boarding workshops and developed numerous how-to documents on developing budgets and on accessing and working on the platform.

A detailed report of activities completed under this task can found in the Task 39 Final Task Report (EED2-FTR-039), dated 10/31/2018.

Task 41 – Enabling EOSDIS Data Usage

Under Task 41, Raytheon provided continuing support for the HDF5 data format and supported the DAACs, SIPS, and other critical HDF users. Raytheon added comprehensive examples for new data products, and updated the existing examples for ASDC, LP DAAC, and NSIDC data products. Raytheon updated the HDF4 and HDF5 handler samples and demo pages, added examples for MOD16A3 and MYD16A3 products, added demos for OMPS-NPP, OMI-MEaSUREs, SMAP, and other missions, and created an instruction page for accessing NASA HDF5 files via Hyrax.

Raytheon provided HDF Helpdesk support to the HDF4 and HDF5 community, including programmers, analysts, and other NASA science software team members. Raytheon launched the Service Desk on 12/31/18, which allows the HDF Helpdesk to transparently track issues and facilitates communication with Helpdesk users.

Raytheon supported metadata standardization activities by providing a resource to co-chair and lead the ESDSWG Dataset Interoperability Working Group (DIWG) activities. The editor of the ESDS-RFC-036 document (Dataset Interoperability Recommendations for Earth Science: Part 2), successfully led the efforts to conclude the review process.

Raytheon released HDF5 1.10.4 and 1.10.5, which added chunk query functions that allowed OPeNDAP to access raw data without using the HDF5 library. Raytheon also released the HDF4 to HDF5 Conversion Toolkit version 2.2.4, HDF Product Designer Server version 1.6.1 and 1.6.2, HDF4 and HDF5 OPeNDAP Handlers, HDF-EOS2 dumper, and EDF-EOS5 to netCDF-4 Augmentation tool 2.6.

Raytheon also provided sustaining engineering for OPeNDAP, which included Hyrax versions 1.15.4 and 1.16.0. Raytheon implemented a Continuous Integration / Continuous Delivery (CI / CD) process for Hyrax that improved the efficiency in software integration testing and release.

A detailed report of activities completed under this task can found in the Task 41 Final Task Report (EED2-FTR-041), dated 10/30/2019.

Task 42 – SDPS Sustaining

Under Task 42, Raytheon conducted provision of resources, effective budget and cost management and schedule execution to complete the task requirements and support Earth Science endeavors,

including supporting the ESDIS goals of increased applications on the NGAP platform to support NISAR and SWOT missions and providing additional focus on IT Security activities.

Raytheon assisted ESDIS with developing and enhancing a Cost Management framework for the Earthdata Cloud development effort to enhance the single-year cost estimation spreadsheet and to develop the seven-year Planning, Programming, Budgeting, and Execution (PPBE) estimation spreadsheets. Raytheon implemented the PPBE spreadsheet across the ESDIS Cloud effort and completed 31 PPBE spreadsheets that have been integrated into ESDIS's overall budgeting and forecasting process. Raytheon also worked closely with ESDIS to implement Threshold alerting on all AWS accounts managed by CloudTamer.

Raytheon produced four software update releases of the SDPS software (9.5, 9.6, 9.7 and 9.8), which added support for VIIRS products, contained HEG modifications to support SMAP products, provided valids for GEDI mission data, added support for ICESat-2 ATLAS preliminary operational products, and increased performance for HEG MODIS service requests.

Raytheon modified the UMM-Var generation (UVG) tool by implementing selection of Science Keywords based on variable long name and definition. Raytheon also provided support to subsetting, reformatting, grid mapping, and reprojecting Earth Science data, to support both NSIDC and Standalone HEG. Raytheon improved the granule deletion utility for LP DAAC, increasing processing ability by as much as 25%.

Raytheon identified Nagios XI as a comprehensive monitoring system for mission-critical components and conducted on-site training at all three ECS DAACs. Raytheon transitioned from the TestTrackPro trouble ticketing tool to the Atlassian Jira tool suite, providing significant developer performance gains and improving the alignment of the SDPS Development and Infrastructure teams.

Raytheon acquired sample GEDI, ICESat-2, SMAP, and VIIRS data files from NSIDC and LP DAAC and prepared the data for testing new and enhanced data transformation software. Raytheon also ingested data from non-ECS DAACs to support the development and testing of the Unified Metadata Model-Variables (UMM-Var) capabilities. Raytheon prepared MOPITT, SAGE III/ISS, and TES data to support the revised Performance Verification Center (PVC) workload specification, and delivered new MOPITT, MISR, and TES Earth Science Data Types (ESDTs) to ASDC. Raytheon also participated in SWOT metadata-related telephone conferences, reviewed proposed Unified Metadata Model for Granules (UMM-G), Collections (UMM-C), Services (UMM-S), and Tools (UMM-T) revisions, and provided comments and suggestions on supporting SWOT-unique requirements.

Raytheon conducted a study to evaluate various options for backup and archival of the EOSDIS data stored in ESDIS Earthdata Cloud (EDC) platform running on Amazon Web Services (AWS).

Raytheon regularly evaluated daily and monthly ingest rate information collected from the DAACs, briefings and presentations, and updated future growth plans for additional disk and tape capacity in support of forward ingest processing at NSIDC, ASDC, LP DAAC and the PVC. Raytheon also completed the specifications of COTS Technology Refresh and Capacity Increases needed for FY2020.

A detailed report of activities completed under this task can be found in the Task 42 Final Task Report (EED2-FTR-042), dated 10/30/2019.

Task 43 – Earthdata

Under this task, Raytheon continued developing, evolving, and sustaining software for the subsystems sustained under Task 33.

Raytheon performed extensive development and system engineering and used the EED-2 SAFe / agile processes to make enhancements to Earthdata Login, ECC and Conduit Web in order to improve functionality, scalability, performance, and reliability. Raytheon implemented a less expensive search capability for the Earthdata website and Developer Portal using Search.gov SaaS to replace Google Search Appliance (GSA), which had reached end of life; as this was the first use of a SaaS product in the Earthdata suite, Raytheon obtained special approval from NASA to incorporate a SaaS product into the Earthdata solution suite.

In preparation for moving Earthdata to the Cloud, Raytheon decommissioned the Developer Portal in its original manifestation, and successfully moved all the documentation from the Developer Portal to other locations, such as a public endpoint in the individual applications, or in a public wiki space. Raytheon also moved CMR and began moving the Earthdata Code Collaborative (ECC) from the URS3 API to the URS4 API.

Raytheon continued to maintain the developer environments, SIT/alpha, UAT/beta, Contingency and Operations environments for Earthdata Login. The Test and Production environments reside in Building 32, Room C101. The system is designed for manual failover to a contingency site in Building 13 in the event of a disaster. All systems were upgraded to RHEL7 operating system. Raytheon deployed numerous COTS software updates for EED-2 Splunk system and Infrastructure Shared Services for such COTS products as Red Hat Enterprise Linux, Oracle Linux, Splunk, vSphere, Java and VMWare Backup Appliances. This effort included monthly OS updates for all servers, security fixes, and maintenance patches.

Raytheon discovered hardware issues that were causing occasional reboots of Splunk Indexers, procured new servers, and began working with Splunk to replace the indexers. Raytheon also procured and inventoried all hardware for the Splunk Infrastructure technical refresh.

As requested by ESDIS, Raytheon continued working toward providing continuous integration and continuous deployment (CI/CD). Raytheon improved the scope of the static dependency vulnerability scanning by prototyping analyzers for Clojure, Node and Python based applications. Raytheon also prototyped and implemented both Selenium and chromedriver-based UI automated testing tools. Additionally, Raytheon led the upgrade process for the Puppet Enterprise installation, driving forward an automated, robust solution for managing modules within Terraform to independently manage accounts and modules in the NGAP 2.0 infrastructure code.

A detailed report of activities completed under this task can found in the Task 43 Final Task Report (EED2-FTR-043), dated 10/30/2019.

Task 44 – GIBS in the Cloud and Cumulus Development and Operations

Under this task, Raytheon led the Cumulus team in technical architecture, technical execution, and systems engineering in alignment with SWOT deliverables, and guided the overall Cumulus system architecture and operations. Raytheon engaged and collaborated with stakeholders, and engaged in a working group for DAAC and GiTC operators and dashboard tooling led by PO.DAAC to determine upcoming user needs. Additionally, Raytheon delivered 100% of functionality for key SWOT milestones, and developed and evolved the Cumulus codebase to meet the needs of integrators and operators from PO.DAAC, ASF, GHRC, NSIDC, GIBS, GESDISC,

LPDAAC, ORNL, and ASDC. Raytheon also on-boarded and oriented the latter four DAACs to Cumulus.

Raytheon updated network access and added support for Launchpad authentication to its API and authenticating to CMR via Launchpad in support of NGAP's ATO assessment and NASA security policies. Raytheon also added support for granules ingested with UMM-G JSON metadata, as requested by the SWOT mission. Raytheon supported efforts by GHRC and PODAAC to store data in different temperature storage locations to aid in backup, recovery and failure scenarios, and supported ingest, archive, metadata submission, and direct download for browse and documentation files. Raytheon also supported two studies: exploration of alternative cloud backup solutions for Level 0 data and an analysis of Dataset Migration Factors (a sub-team of the Development Project Management Board).

Under the Cloud Based Metrics effort, Raytheon developed the Cloud Based Metrics requirements, incorporated feedback from a large Jama review with multiple stakeholders and reworked the requirements to better capture the desired flexibility in visualization creation and customization. In addition to this work, the Raytheon completed an upgrade of the commercial ELK stack to AWS Open Distro, which provides access to single sign-on (SSO), role and user access management, and other advanced security features. Raytheon met with the NGAP and ESDIS Security teams to discuss overlap in current ELK efforts and identify opportunities for reuse and cost reductions.

Raytheon developed a joint cost model with the Cumulus team and submitted it to ESDIS for future budgetary planning. This model included cost estimates for NGAP accounts for both computing and storage. Raytheon also completed the User and Operations Guides for the Cloud Based Metrics System.

Under the GIBS in the Cloud (GitC) effort, Raytheon supported SES II and JPL in developing and deploying the GitC ingest and OnEarth systems to the NGAP 2.0 sandbox. Raytheon assisted NGAP in discovering issues in both the underlying NGAP 1.x and 2.0 platforms, which ultimately benefits all applications who will be hosted by NGAP.

A detailed report of activities completed under this task can found in the Task 44 Final Task Report (EED2-FTR-044), dated 10/30/2019.

Task 45 – Common Metadata Repository Evolution

Under Task 45, Raytheon led the Unified Technical Committee's biweekly meetings to ensure that ESDIS development efforts, both inside and beyond the EED-2 program, were communicated with the DAAC systems engineers and user services staff. Raytheon tracked and reported metrics on performance, availability, inventory holdings, software quality as determined by blocker bugs, and usage for CMR, EDSC, and related tools.

Raytheon performed sustaining engineering and evolution as requested for the CWIC Prototype GUI (CWICSmart) and CWICSmart OpenSearch Validation Tool, including security updates and migration to the NGAP 2.0 environment.

Raytheon performed several EDSC user interface / user experience (UI/UX) improvements, including faster loading times of panels within the application, seamless transitions from collection search to project configuration/customization, wait times for datasets needing to be customized, and laying the foundation for upcoming responsive design work. The EDSC, via its 508-compliant partner site Access, is compliant with NASA website requirements.

Raytheon worked with ESDIS and NGAP 2.0 to plan a path forward to pioneer serverless architecture for EED-2. This includes leveraging cloud-native technologies and refactoring the EDSC to use new tools that have a wider adoption rate than the current technology stack. Raytheon also supported ICESat-2 to give end users necessary functionality while reducing the operational load on NSIDC.

Raytheon also identified an overlap and opportunity related to an intersection between Earthdata Search and Giovanni; Earthdata Search then added support to allow a user to easily navigate from Earthdata Search to Giovanni.

Raytheon managed metadata quality and metadata curation in the CMR, advancing the utilization of ESDIS' metadata curation tools through integration, eliminating redundancies and expanding on the strengths and capabilities of the MMT, Curation Dashboard and KMS. Raytheon migrated the Curation Dashboard to EED-2 Infrastructure, implemented a collection-to-collection link from the Curation Dashboard to the MMT, added Dashboard ACL management to the MMT's "Manage CMR" capabilities, and began development of the MMT for "non-NASA users" ("draft MMT"). In support of the SWOT mission, Raytheon provided a new ability for users to ingest granule records using the UMM-G JSON format, translated UMM-G records into ECHO-10, DIF-10, and ISO MENDS and vice versa, and prepared sample records of UMM-G, ISO MENDS, and ISO SMAP with a mapping spreadsheet that defines how the CMR will map elements between the different specifications. UMM-S records were created that correspond to existing OPeNDAP and EGI (SDPS services). Finally, in order to better handle the large number of UMM-Var records compared to other UMM-x concepts, Raytheon developed the UMM-Var Generation (UVG) UVG-API.

With a focus on reducing the legacy GCMD / IDN footprint when possible, Raytheon prepared GCMD / IDN apps for migration to EED-2 hardware. All apps were migrated to Bamboo for deployment management, legacy software dependencies were removed, security issues were addressed and software was decommissioned. Additionally, Raytheon evolved an end-to-end workflow for accessing customized, serviced data and deployed the full suite of functionality to the UAT environment. In support of the migration effort to NGAP 2.0, Raytheon migrated CMR's SIT environment to NGAP 2.0.

In response to critical flaws in the way CMR data was being updated on data.nasa.gov, Raytheon worked with the data.nasa.gov team to purge tens of thousands of outdated, deprecated, or duplicate records in the data.nasa.gov database. Raytheon developed a functioning portal to deliver fresh CMR metadata to data.nasa.gov and implemented automated processes to push fresh CMR data to data.nasa.gov on a weekly basis.

Raytheon updated the Visio Rack Diagrams of Building 32 systems to reflect the migration of all remaining Task 45 hardware to the Task 43 Earthdata baseline.

The process, tool, and system enhancements described above have allowed the CMR to keep up with client and EOSDIS data growth. The CMR's granule inventory increased by ~10%. The CMR serviced over 160 million searches and maintained over 99.9% availability. Raytheon routinely collected metrics on CMR system holdings, availability, performance, and usage, and distributed these metrics to ESDIS. Raytheon provided 8 hour / 5 day attended server support and supported deployment of new functionality as approved by the review board.

A detailed report of activities completed under this task can found in the Task 45 Final Task Report (EED2-FTR-045), dated 10/30/2019.

Task 46 – Sentinel Gateway

Under Task 46, Raytheon procured two Juniper QFX5100 Network Switches and a Juniper SRX5100 Firewall to replace the network devices in the NSG UAT environment that have reached end of service life. Raytheon also procured two HP 10 GB Ethernet Network Interface adaptors and installed them in the nsguap01 and nsguap02 servers to correct the firmware update issues encountered on those servers.

In support of the Sentinel-3A OLCI transition from S3 Pre-Operational hub to Open Access hub, Raytheon enhanced the NSG application to fetch S3A OLCI data from Open Access hub while acquiring other S3A data from S3 Pre-Operational hub. Raytheon scaled up the system with additional data acquisition job threads to support the increased data volume to support Sentinel-3A re-processed data products. In support of the Sentinel-3B (S3B) mission, Raytheon enhanced the Operator tool to be able to reconcile inventories between NSG and ESA data hubs. Raytheon also updated the NSG Operator GUI to be able to monitor S3B ingest and distribution status. Subsequently, Raytheon conducted the NSG Release 4.0 Operational Readiness Review (ORR), which marks readiness for NSG to support the S3B mission.

Raytheon reconfigured NSG to acquire newly-available reprocessed Sentinel-5P Level 2 granules (including HCNO, NO₂, and SO₂ products) and distributed them to GES DISC. Raytheon was also directed by ESDIS task monitor to acquire three additional Sentinel-5P Level 2 products (L2__NP_BD3, L2__NP_BD6, and L2__NP_BD7) from the ESA Sentinel-5P-PreOps hub. Raytheon also reconfigured NSG core application to use query chunk size of 100 when querying ESA International Access hub. Raytheon deployed the NSG NodeJS API tool on two application servers to provide system redundancy, and enhanced the three-way reconciliation tools to be able to reconcile with ESA data hubs using ESA publication times.

Raytheon released NSG versions 4.1, 4.2, 4.3, and 4.4, which operationalized the NSG-DAAC reconciliation functionality, allowed NSG to ingest all Sentinel-3A and 3B products from the ESA International Access Hub, added discovery and acquisition capabilities for Sentinel data based on ESA publication time, implemented public key encryption of user credentials for accessing ESA data hubs and upgraded Node JS APIs from *http* to *https* protocol.

A detailed report of activities completed under this task can found in the Task 46 Final Task Report (EED2-FTR-046), dated 10/30/2019.

Task 48 – SAFe for ESDIS

Under Task 48, Raytheon successfully executed Program Increments (PIs) 18.4, 19.1, 19.2, and 19.3 and conducted planning sessions for PI 19.1 (January 23-24, 2019), PI 19.2 (April 10-11, 2019), and PI 19.3 (July 10-11, 2019). Over 120 people attended each session. Participants included staff from EED-2, ESDIS, DAACs, NASA's CIO office, JPL, University of Alabama Huntsville, Development Seed, SES II, and other external EED-2 entities. Raytheon also conducted planning activities in preparation for PI 19.4, which occurred outside this task's period of performance.

During the PI Planning sessions, Raytheon continued the Earthdata Trivia in the plenary session and added in a trivia game into the individual train Management Plan reviews. Raytheon also

introduced the Mission Update, presented by the Mission Engineer, to keep the participants abreast of the SWOT, NISAR, and GEDI missions and had an outside speaker on Cybersecurity.

Additionally, Raytheon collaborated with ESDIS to develop a new risk framework that mirrors the NASA Risk Management Guidelines and allows for risks to be elevated from the trains. Raytheon developed a common PI closeout reporting framework that allows ESDIS to insert components into their management reports.

Raytheon trained twenty-five ESDIS-funded contractors in both the SAFe Scrum Master (SSM) course in December 2018 and the SAFe Product Owner / Product Manager (POPM) course in January 2019.

A detailed report of activities completed under this task can found in the Task 48 Final Task Report (EED2-FTR-048), dated 10/30/2019.

Task 49 – NASA-Compliant General Application Platform

Raytheon coordinated with ESDIS Security (ES) to prepare for an external security audit and renewal of the Earthdata Cloud Authority to Operate (ATO) achieved under Task 39. This collaboration yielded new time-sensitive requirements and priorities for the NGAP development teams including the creation of a centralized, secured, and authoritative copy of all security relevant logs from the Earthdata Cloud. This “Golden Archive” provides the ES team with platform-wide visibility for security relevant activities, cloud resource inventory, configuration management, change detection, and various other key contributors to assuring a positive outcome for future external security assessments.

Raytheon invoked the recently released “Freeze-Spend” and “Circuit Breaker” features as actions on all non-production NGAP 2.0 accounts, reducing spending rates and avoiding cost overruns during the 2019 government shutdown. These actions were reversed following the government re-opening without any issues or further disruptions to application owners.

Raytheon collaborated extensively with ASF and other application stakeholders on the design of the planned data egress cost control capability and Internet Services suite of features. Raytheon curated requirements, prepared numerous design iterations, conducted cross-team design review sessions, and performed impact analysis with inputs from application owners, ES, NetOPS, and ESDIS management on various alternatives.

The successful release of the Earthdata Cloud Platform’s (EDC) Go-Live event in July, 2019, signaled that the EDC was ready to host non-EED-2 applications accounts and a subset of mission data accounts. This resulted in significant increase in the usage of the EDC platform, which is notable as NGAP is the main component of the EDC.

A detailed report of activities completed under this task can found in the Task 49 Final Task Report (EED2-FTR-049), dated 10/30/2019.

Task 51 – Enabling EOSDIS Data Usage

Under Task 51, Raytheon provided technical support to the HDF4 and HDF5 community, including users of ESDIS data products and the users and developers of HDF-EOS and HDF-EOS5, via the HDF Helpdesk. The HDF Helpdesk received 446 requests. 54.3% were resolved within 4 hours, 73.3% were resolved within 24 hours, and 85.6% were resolved within 48 hours.

Raytheon continued the customer outreach efforts performed under earlier tasks, and uploaded a tutorial video and answered questions on the HDF-EOS YouTube channel at <https://www.youtube.com/user/hdfeos>.

Raytheon continued to co-chair the ESDSWG Dataset Interoperability Working Group (DIWG).

Raytheon's HDF team released the following software: HDF5 1.10.6 and 1.10.7 (which contained AWS S3 and HDFS drivers, enabling data access on the AWS S3 and Hadoop file systems), HDF5 1.12.0 (which contained a new feature Virtual Object Layer (VOL) allowing HDF5 applications to access data on non-POSIX storage), HDF4 4.2.15 (which updated the CMake build system and ported HDF4 to macOS 10.13, 10.14, and 10.15), and HDFView 3.1.1, which improved handling of netCDF3 files.

In order to improve Hyrax server performance, Raytheon's OPeNDAP and HDF teams modified the Hyrax data server by eliminating the unnecessary construction of metadata objects for the data response. In support of the multi-cloud demonstration work, the OPeNDAP team set up a Hyrax prototype in the Google Cloud using the same Docker image as is used in the NGAP deployments. In addition, the team deployed a Hyrax prototype system in the Microsoft Azure cloud using Azure's Kubernetes support, and demonstrated Hyrax running in both cloud environments on August 28, 2020.

Raytheon's OPeNDAP team released Hyrax versions 1.16.1 and 1.16.2, which added Earthdata login authentication support and contained the structure needed for deployment to the NASA NGAP 2.0 system.

In support of the Harmony Cloud Services Framework development, Raytheon implemented basic services in support of the SWOT mission, including integration with a PO.DAAC-developed Level 2 spatial and variable subsetter and an EED-2 developed reprojection tool and reformatter. Raytheon also evolved the system to support the Sentinel-6 ORR. This included implementation of additional transformation services such as the ability for users to subset by shapefiles and regrid data via an OGC API directly or via a QGIS plug-in built on top of Harmony. Additionally, Raytheon modified Harmony to handle requests in an asynchronous manner, which also allow users to process the resulting data in the cloud, thus avoiding data download. To access results in a more cloud-efficient manner, users are presented with a link enabling them to use the AWS S3 API directly on their data results.

Raytheon also built the EOSDIS Zarr Store, a novel library allowing ESDIS to archive data in rich NetCDF format in AWS while allowing users to access these data via standard Zarr libraries. Raytheon built out all of the initial "shared" components integrations, including Earthdata Login, Unified Metadata Model, CMR, and the Metrics system, allowing DAACs to plug and play dataset-specific backend services. Raytheon worked with GES DISC to integrate their STAC translation services, and planned the integration architecture of LP DAAC's AppEERs application. Additionally, Raytheon onboarded an NSIDC developer as part of the core Harmony team, and teamed with ASF for evolution and maintenance of a Raytheon-built GDAL prototype.

A detailed report of activities completed under this task can found in the Task 51 Final Task Report (EED2-FTR-051), dated 9/30/2020.

Task 52 – SDPS Sustaining

Under this task, Raytheon provided a Mission Engineer, who maintained mission roadmaps to communicate mission needs across a broad group of organizations, including ESDIS, PO.DAAC,

ASF and the three SAFe trains, ensuring that the Cumulus system was complete with requirements for SWOT Operations Qualification prior to PO.DAAC's testing commencement, and that the functionality needed for the Sentinel-6 ORR was completed on time. The Mission Engineer also shared SWOT best practices with the ASF NISAR team, facilitating a successful Level 3 Requirements review and coaching ASF on the reuse of SWOT requirements.

Raytheon produced three software update releases of the SDPS software (9.9, 20.1 and 20.2). Release 9.9 added support for the Global Ecosystem Dynamics Investigation (GEDI) Level 2A Elevation and Height Metrics Data and Soil Moisture Active Passive (SMAP) Level 3 and Level 4 gridded products. Release 20.1 included a feature to handle non-Climate Format (CF) datasets and handling of three-dimensional data fields, both of which were needed for the SMAP mission. Release 20.2 updated the Bulk Metadata Generation Tool (BMGT) software to support NASA Launchpad authentication required to access the CMR. Raytheon also modified a custom legacy ECHO form (used for granule search and order data requests) in order to comply with NAMS.

Due to required NASA security requirements, all communications protocol within the SDPS environment was transitioned from the HTTP non-secure transfer mechanism to the HTTPS secure mechanism. SSL certificates were installed on internal hosts to support the securitization of all internal web applications.

Raytheon conducted a specification workshop with LP DAAC, using the ICESat-2 subsetter framework as a guide to provide subsetting and formatting services for GEDI Low-Level Data Products. GEDI Level 1B, 2A and 2B operational data became public on January 21, 2020. Raytheon delivered an innovative solution that enables Cumulus-hosted ATL-3 and ATL08 data to be subsetted by variable using the Harmony cloud services environment. Raytheon also added support for the MODIS Multi-File Bidirectional Reflectance Distribution Function and Albedo Global Gap-Filled, Snow-Free product (MCD43GF).

Raytheon monitored the ECOSTRESS mission volumes and analyze other archive projection changes due to new data reprocessing campaigns at LP DAAC. Raytheon determined the size and specification of the required ECOSTRESS expansion and provided ESDIS with two ROM cost estimates.

In support of NSIDC, Raytheon re-engineered the generic trajectory-level subsetter to process the SMAP L1/L2 data products, provided subsetting support in the form of variable and spatial subsetting for the Snow Cover Daily SIN Grid product (VNP10A1) for the VIIRS mission, and added subsetting capabilities for two new ICESat-2 products: the weekly and monthly gridded atmosphere products ATL16 and ATL17.

Raytheon also helped ASDC complete their long-running data migration process from LT04 to LT07.

Raytheon provided support for PostgreSQL "parallelism" for the deletion cleanup and archive check utilities. Raytheon also transitioned a legacy Configuration Change Request (CCR) tool, which ran on Windows Access 2003, to an innovative Java based web application on the ECS Development Network (EDN) integrated with Jira, providing increased visibility on the workflow status of pre-approved CCRs and Engineering Change Orders. Raytheon also created utilities to support the transition from RHEL 6 to RHEL 7, allowing DAACs to manage their specific configuration parameters in one place.

Raytheon conducted two hardware tests for the Level Zero and Repositories Data Store (LZARDS) Proof of Concept (POC) infrastructure in GSFC Bldg32, C101 computer room. The test results validated that sufficient network bandwidth to AWS was available to provide for the required 1.8 gigabytes per second throughput. Additionally, the hardware component test results validated that the selected LZARDS hardware COTS can provide for the required sustained ingest and backup throughput of 20TB per day. Raytheon then specified and procured LZARDS non-production hardware components.

Raytheon acquired sample GEDI, ICESat-2, MODIS, and VIIRS data files from NSIDC and LP DAAC and prepared the data for testing new and enhanced data transformation software. Raytheon acquired and prepared sample AMSR-E, ASTER, ICESat-2, MODIS, and SMAP data for the PVC Ingest and Data Access Workload Specifications. Raytheon also participated in the ESO formal review of the Unified Metadata Model for Collections (UMM-C). In support of ASDC's upcoming TEMPO mission, Raytheon reviewed, corrected, and ingest tested draft TEMPO granule metadata. Raytheon also helped ASDC synchronize the collection metadata holdings in their CAMP system with the ESDT collection metadata holdings.

Major engineering services and activities performed by Raytheon for Contract Year 5 COTS Technology Refresh and capacity expansion include Delivering the Technology Refresh of four existing End of Service Life (EOSL) VNX series 1 arrays at NSIDC and LP DAAC, delivering additional LTO media to NSIDC and ASDC to match the Online Archive Ingest requirements at NSIDC and at ASDC, and delivering / installing StorNext Storage Manager Software (version 6.3.1.1) and ten additional HPE ProLiant BL460c G10 servers for the migration to RHEL7. Raytheon also procured the remaining storage capacity needed to meet LP DAAC's projected storage needs for ECOSTRESS mission in FY2020.

Raytheon conducted a Commercial Smallsat Data Acquisition Program (CSDAP) Study to analyze and estimate the work required to expand the current architecture in order to handle the long term archive and distribution of CSDAP data.

A detailed report of activities completed under this task can found in the Task 52 Final Task Report (EED2-FTR-052), dated 9/30/2020.

Task 53 – Earthdata

Under this task, Raytheon sustained the Earthdata subsystems and Completed the Rails 5.2 upgrade of all Earthdata Ruby applications (Conduit CMS, Feedback module, Earthdata Status, Tophat2) and Earthdata Login. Raytheon also decommissioned the Earthdata developer portal and its cloud infrastructure, and successfully redirected users to the API section on Earthdata web page. Raytheon migrated all user and application data and related functionality from LDAP to PostgreSQL, and deployed a contingency application, the "Earthdata Login Cloud-Hosted Contingency Site," with limited functionality in the cloud that will allow end users to download data in case of a sustained EDL outage. Raytheon used Sortsite (a 508 compliance check tool approved by NASA) to audit all Earthdata applications, and all 508 Compliance related issues have been addressed for the Feedback Module. Finally, Raytheon made performance improvements to the Earthdata website, increasing processing speed from 70 to 400 requests per second.

Raytheon added 12 new applications to Earthdata Login in the Operations environment and 29 applications in the UAT environment. Raytheon also supported GCMD KMS and Keyword Search through the installation of GCMD MySQL database in all environments and KMS Redis database in the SIT and UAT environments. Hardened and otherwise improved ongoing security posture

for the Earthdata Sonatype Nexus Maven Repository. Finally, Raytheon onboarded the COVID-19 dashboard application for the IMPACT/HQ project at <https://earthdata.nasa.gov/covid-19>, using the BigIP F5 features to proxy the /covid-19 path for an AWS-hosted application.

During the Task 53 period of performance, the Earthdata Production system experienced an increase of 144,923 users, with a weekly growth averaging about 2,954 users. The Earthdata Login system served 1,370,156,482 requests for URS4, and provided consistently high availability of 99.97% for URS4 and 99.98% for URS3. There were two degraded service events in Earthdata Login, which were resolved as efficiently as possible by working collaboratively with all stakeholders.

A detailed report of activities completed under this task can found in the Task 53 Final Task Report (EED2-FTR-053), dated 9/30/2020.

Task 54 – Cumulus Development and Operations

Under Task 54, Raytheon onboarded three new DAACs: LPDAAC, ORNL, and GES DISC to Cumulus. The team also began onboarding ASDC and NSIDC. The Cumulus system continues to support the SWOT and NISAR missions, with SWOT Operational Qualifications tracking far ahead of schedule and the Cumulus team participating in NISAR requirements review. Cumulus also supported GHRC going into parallel operations.

Raytheon released Cumulus 1.16, switching all deployments to use Terraform instead of Kes, an external tool. Raytheon also updated the distribution deployment configuration for specifying a custom bucket map for the Thin Egress App (TEA), which gives the users the option to obscure their bucket names in their distribution URLs.

Raytheon implemented bulk granule operations and near real time ingest metrics, and tackled technical debt items, such as updating React, removing unused code, and revising package structure. Raytheon also enhanced the efficiency of testing efforts by reducing build time in CI and allowing the API to run locally for quicker dashboard testing.

In addition to implementing features and integrating user feedback, Raytheon continued to make forward-looking contributions to the data backup efforts via participation in the Operational Recovery Cloud Archive (ORCA) and LZARDS Working Groups.

For the Cloud Based Metrics effort, Raytheon defined three distinct pipelines for ingesting log data (distribution and ingest/archive) to what's been deemed the "Metrics Data Pipeline." Raytheon onboarded six new tenants (DAACs and EOSDIS Services) to the User Acceptance Test (UAT) and Production environments and set up visualizations to help them track ingest, distribution and services metrics in their transition to cloud.

A detailed report of activities completed under this task can found in the Task 54 Final Task Report (EED2-FTR-054), dated 9/30/2020.

Task 55 – Common Metadata Repository

Under this task, Raytheon migrated the User Acceptance Test (UAT), Workload, and Production environments from NGAP 1.0 to NGAP 2.0. The migration to NGAP 2.0 brought both performance improvements and powerful new cost controls to the CMR platform. Since the migration, there has been a 50% improvement in both CMR search query and ingest times at the 50th and 75th percentiles, and a 25% improvement at the 95th percentile.

Raytheon also upgraded to an ElasticSearch 7.5.2 cluster. Using the new cluster, granule searches are processed in 199ms at the 95th percentile, compared to 227ms using the old cluster, for a 13% improvement. At the 99th percentile, granule searches are processed in 495ms vs. 696ms, an improvement of 29%.

To support the SWOT mission, Raytheon added horizontal spatial resolution in the metadata and standardized reporting of granule size. Raytheon also added standardized measurement names as they appear in the KMS, the ability to search for collections and granules that intersect a river center line, and a point-and-radius search capability.

Raytheon advanced the utilization of ESDIS's metadata curation tools through integration, eliminating redundancies, expanding on the strengths and capabilities of the MMT, Curation Dashboard and KMS, and reducing the legacy GCMD / IDN footprint. This included conducting pathfinder testing and completed the development of MVP features for the dMMT, documenting a formal migration and retirement plan for legacy GCMD applications, redirecting all Search2 portals to Search3 portals, and retiring certain non-essential software and services.

In support of UMM-Var Autogeneration, Raytheon deployed UVG-API to production environment, and provisioned access for GES DISC, PO.DAAC and GHRC for variable generation. Raytheon also revised the UMM-Var JSON schema to enable CMR users to refine queries by measurement name. Raytheon developed, vetted, and published UMM-Var 1.7 to support hierarchical data products via end-to-end workflows.

Raytheon launched a pathfinder program with OB.DAAC to explore migrating DAACs to Launchpad Authentication for CMR Ingest. Raytheon also Cross-referenced the GCMD Atmosphere, Land Surface, and Ocean keywords with the NOAA TPIO Keyword Set and reported keyword matches, near matches, and keywords needing further discussion to the NASA customer and NOAA / USGS partners. As a cost savings initiative, Raytheon consolidated portals under a single infrastructure by creating an EDSC portal enabling discovery of data collections offered by the CEOS International Directory Network (IDN)

A detailed report of activities completed under this task can found in the Task 55 Final Task Report (EED2-FTR-055), dated 9/30/2020.

Task 56 – Sentinel Gateway

Under this task, Raytheon supported five Sentinel missions (Sentinel-1A, 1B, 3A, 3B, and 5P) and five client systems / DAACs: ASF, LAADS, OB.DAAC, SMAP, Science Data System (SDS), and GES DISC. Raytheon configured the NASA Sentinel Gateway (NSG) system and acquired Sentinel-5Preprocessed Level 2 Cloud and O3 products from the European Space Agency (ESA) Sentinel-5P Pre-Operational Data Hub and distributed them to GES DISC. Following ESA's announcement that they would be switching to a v2.1.3 processor baseline for five Sentinel-5P Level 2 products, Raytheon modified the NSG code such that the Product Delivery Records (PDRs) generated have their DATA_VERSION field correctly reflect the new processor baseline for the affected products.

Raytheon also configured the NSG to handle Sentinel-3A and 3B Synergy products (i.e. SYN Land Surface Reflectance products), acquired them from the ESA, stored them until the LAADS system was ready for ingest, and then distributed them to LAADS and OB.DAAC. Raytheon acquired the Sentinel-3A and 3B reprocessed products that were published on the ESA Open Access Hub in

several batches over a period of six months, from March to August of 2020, and distributed them to OB.DAAC and LAADS.

Raytheon streamlined the Sentinel data distribution workflow by enhancing the NSG core application and Node JS Application Programming Interface (API) to automatically handle and re-stage PDRs in response to Product Acceptance Notifications (PANs) received with a disposition value of “Request Cancelled.” Raytheon replaced the IsiLon storage units for the User Acceptance Test (UAT) and Production environments, migrated over 500TB (Terabytes) of Sentinel data to the replacement storage nodes, and logically decommissioned the end-of-life storage nodes.

Raytheon delivered NSG releases 4.4 through 4.7. These releases provided public key encryption of user credentials for accessing ESA data hubs, automatically redistributed of granules after receiving a class of PAN error messages to better automate and streamline the distribution workflow, efficiently acquired reprocessed granules or NSG missing granules from ESA Data Hub, and reduced NSG data retention period from ninety to sixty days for all Sentinel missions due to the smaller storage capacity in the replacement IsiLon storage cluster.

To ensure that ingest and distribution throughput requirements were met, Raytheon monitored network traffic between ESA data hubs and the NSG and between the NSG and the DAACs, as well as between the NSG and the DAACs. In addition to the forward processing data products, Raytheon also acquired re-processed data products as they are published. This included the successful acquisition and distribution of Sentinel-5P as well as Sentinel-3A and 3B reprocessed data products. To ensure the reprocessed data stream did not negatively impact the timely acquisition and distribution of forward processing data, Raytheon set up the reprocessed data streams separately and acquired them based on the data load and available bandwidth.

A detailed report of activities completed under this task can found in the Task 56 Final Task Report (EED2-FTR-056), dated 9/30/2020.

Task 58 – SAFe for ESDIS

Under this task, Raytheon executed Program Increment (PI) 19.4, and planned and executed PIs 20.1, 20.2, and two sprints of PI 20.3. PI Planning 20.1 had over 200 people attend. Raytheon conducted virtual planning sessions for PIs 20.2 and 20.3; each had over 220 attendees. Participants included staff from EED-2, ESDIS, DAACs, NASA’s CIO office, JPL, SES II, and other external EED-2 entities.

Raytheon began conducted PI Planning sessions virtually, and created a Risk Plan with Contingency options for mitigating any challenges that arise with a virtual scaled event. Raytheon identified a major risk of tooling reliability for accessing virtual artifacts, and created a backup plan that outlined secondary options for each artifact. This plan allowed each SAFe team to continue planning if one or more of the artifact tooling options failed to work during the course of the virtual PI Planning event. To mitigate the major risk factor of a communication breakdown, Raytheon created a Communication Plan for Emergency Contacts, ESDIS Leads, Train Leads, and Team Members. This plan provided a comprehensive list of contact information for each of the core PI Planning participants, locations for the planning artifacts for each of the train teams, and instructions for any major shift in the planning schedule should an emergency situation arise. In order to virtualize all PI Planning artifacts that had been paper artifacts during previous in-person planning sessions, Raytheon created Trello boards for each Train’s Objectives, Risks, and PI Planning Retrospectives. Raytheon utilized a new roadmap tool, Roadmunk, to visualize high level

tasks for new initiatives, such as the Commercial Smallsat Data Acquisition Program (CSDAP) study.

A detailed report of activities completed under this task can found in the Task 58 Final Task Report (EED2-FTR-058), dated 9/30/2020.

Task 59 – NASA-Compliant General Application Platform

Under Task 59, Raytheon conducted planning, estimation, and stand-up meetings for the development and infrastructure efforts of the Earthdata Cloud. Raytheon developed an AWS Sessions Manager that provides usability enhancements and improved security posture for command-line level access to cloud resources, and an NGAP-managed Amazon Linux 2 AMI that enables features and stability improvements from the upstream vendor and allows EDC tenants to meet ESDIS security requirements. Raytheon also implemented isolated development channels (DEV, EDGE, STABLE) for EDC platform such that infrastructure prototyping can occur in a quarantined channel (DEV) and new infrastructure releases can be evaluated (EDGE) prior to promotion to EDC tenant accounts in STABLE, and completed a critical milestone with operationalizing Enterprise Egress Throttle. Raytheon upgraded the entirety of the EDC platform infrastructure to a new version of Terraform improving the overall security of the EDC and enabling developers to leverage newly released features intended to streamline and optimize infrastructure development.

Raytheon curated requirements, released new versions of the Tenant Run Rules, prepared numerous design iterations, conducted cross-team design review sessions, and performed impact analysis with inputs from application owners, ESDIS Security, NetOPS, and ESDIS management on various alternatives. Additionally, Raytheon hosted engineering meetings with ESDIS Security, NetOPS, and the EMCC.

In order to reduce cost, Raytheon realigned the Cloud Tamer Organizations, prepared the Application Administrator role that delegates user creation privileges to designated NASA Civil-Servants without requiring an NGAP Support ticket, and developed the next version of the PPBE Cost Model spreadsheets.

Raytheon also introduced a Site Reliability Engineer (SRE), is a dedicated full-time staff member focusing on developing software that improves the reliability of systems in production, fixing platform stability issues, and automating tests and health checks to identify issues before they grow to platform problems.

Raytheon coordinated with Enterprise Network Security (ENS) to deliver a beta-version of a new Distributed Oversight application to early adopter tenants. In coordination with the ESDIS Assessment and Accreditation (EAA) team, Raytheon devised an architecture for a continuous integration / continuous deployment (CI/CD) Validator tool to help ensure security compliance of software delivered to the Earthdata Cloud. Raytheon also explored and integrated cloud-specific networking technologies into the Earthdata Cloud in support of improved efficiency, automation, and security. Numerous methods of cross-account networking access were investigated including, traffic mirroring, VPC-Peering, transit-gateways, and VPC Endpoint Services.

A detailed report of activities completed under this task can found in the Task 59 Final Task Report (EED2-FTR-059), dated 9/30/2020.

Task 61 – Enabling EOSDIS Data Usage

Under Task 61, the HDF Group Helpdesk received 244 requests, 48.4% of which were resolved within 4 hours, 18.8% were resolved within 24 hours, and 11.1% were resolved within 48 hours. Raytheon actively participated in technical conferences and working groups, and educated HDF users on the latest HDF software enhancements and best practices for achieving data interoperability and accessibility.

Raytheon continued to co-chair the Dataset Interoperability Working Group (DIWG) activities and participate in relevant activities of external geoscience informatics communities such as ESIP and Climate and Forecast (CF) metadata conventions.

Raytheon made the following software releases available to the user community: HDF5-1.8.22, which supported the AEC compression library and included the AWS S3 and Hadoop Distributed Filesystem virtual file drivers, HDF5-1.10.7, which supported the AEC compression library and added the Splitter and Mirror virtual file drivers, HDF5-1.12.1, which improved performance, fixed vulnerability issues, supported the AEC library, and supported macOS Big Sur and Universal Binaries, HDFView 3.1.2, which displayed NetCDF dimensions in the Object Info tab, and HDFView-3.1.3, which added reading and display of non-standard floating point numbers.

Raytheon's OPeNDAP team updated the Hyrax server to use the latest version of GDAL (3.2.1), updated the DMR++ module with the new thread management capability provided by C++11, and streamlined the OPeNDAP Configuration so that the URL obtained from CMR is treated as valid. Raytheon also implemented the DAP4 variable expression constraint features in the Hyrax FileOut netCDF module and added support for the new version of the GPM Level 3 DPR gridded product per the request from GES DISC.

Raytheon provided several improvements to the Hyrax Build and CICD processing, including moving from CentOS 6 to CentOS 7 (which allowed the use of C++11), migrating the CICD system to a new platform to provide faster builds, and updating the CICD system to support more automatic deployments with versioning.

Raytheon assisted GES DISC by investigating and fixing the issue of certain intermediate netCDF files generated by the GES DISC Hyrax servers avoiding deletion after processing. Raytheon assisted PO.DAAC by investigating why the size of the netCDF-4 file generated from FileOut netCDF module was significantly bigger than the original file size, and found that an HDF5 shuffle filter option should be added to the Hyrax's FileOut netCDF module.

Raytheon improved reliability and performance by reducing the data access failure rate from >11% to 0.4% of requests in serving GHRC data products. Raytheon also improved Hyrax latency in service chaining use cases by implementing the Hyrax optimization algorithm "SuperChunk" that combined HDF5 file chunks to better use the EC2 instance bandwidth to achieve better performance.

In order to integrate HIC with other NGAP services, Raytheon demonstrated Hyrax's ability to receive and pass tokens with other NGAP applications. Raytheon also implemented a method to enable repeatable REST-based data access via OPeNDAP Hyrax services. Additionally, Raytheon began developing a session manager that will enable HIC to better use the AWS Amazon Load Balancer (ALB).

In alignment with Harmony's first goal (service capabilities for interdisciplinary cloud data), Raytheon grew the production environment from 5 to 111 collections, published a user-facing

Python library with interactive notebooks, enabled discovery and access to Harmony services through Earthdata Search, and supported a workshop at AGU evangelizing Harmony led by PO.DAAC and NSIDC.

In alignment with Harmony's second goal (community development), Raytheon amplified Harmony's service capabilities through service chaining, released Harmony as Open Source and published the code to GitHub, and on-boarded the ASF and GES DISC teams and the AppEEARS and Giovanni developers to Harmony.

Under Task 61, the operational support grew significantly as new Sentinel-6 data were ingested into the Earthdata Cloud (EDC) and more DAACs were on-boarded. Raytheon ensured that the operational data services, including Harmony and OPeNDAP, were stable with no degraded service, including during a spike in usage during an AGU workshop.

A detailed report of activities completed under this task can be found in the Task 61 Final Task Report (EED2-FTR-061), dated 8/30/2020.

Task 62 – SDPS Sustaining

Under Task 62, Raytheon conducted an EED-2 Value Stream analysis with the DAACs, ESDIS, and our RTX Agile Framework for Product Development (AFPD) team SME to determine the optimal SAFe structure for keeping up with ESDIS and community needs. This analysis resulted in a decision to move to a four-train configuration, with the existing Data Use Train being replaced by the new Transformation and Search and Discover Trains.

Raytheon produced one release of SDPS software, two software updates, and provided remote support to NSIDC and LP DAAC prior to and during the DAAC installation of Release 20.2. Release 20.2 supported the ICESat-2 Mission by providing Data Access services for the "Land Based Ice Sheets Seasonal Altimetry Heights" and "Gridded Monthly Sea Ice Freeboard" data types. Release 20.2 supported the SMAP mission by providing Data Access services for SPL3SMP and SPL3SMP_E data types. Finally, Release 20.2 enhanced software installation utilities, generating custom code configuration files to reduce installation time by 10%.

Software Update 20.3 enhanced the SDPS ingest processing and polling services, ensuring required ingest workload specifications were met during heavy ingest processing loads (such as mission-critical reprocessing campaigns). Software Update 20.3 also provided the ability to create parameter and spatial subsetting services for ICESat-2 Annual Land Ice Height (ATL11) products to allow science users to retrieve specific ATL11 coverages. Services were also made available for VIIRS and MODIS collections (VNP10A1F, VIIRS/NPP CGF Snow Cover Daily L3 Global 375m SIN Grid and MOD10A1F, MODIS/Terra CGF Snow Cover Daily L3 Global 500m SIN Grid) that also provide subsetting services for these new data products.

Software Update 21.1 delivered software solutions for DAAC priority issues to enable performance improvements when requesting all band names for ATL20 data and optimized capabilities for Data Access services.

Raytheon's Mission Engineer supported the timely completion of the functionality required for the Sentinel-6 mission launch (a key predecessor for the SWOT mission). Additionally, the Mission Engineer helped ESDIS to plan a series of gates in preparation for missions, DAACs and systems going into production.

Raytheon delivered and supported the upgrade of eleven existing SDPS COTS products for all SDPS DAACs. Raytheon worked closely with the ECS DAACs to upgrade all RHEL6 servers to RHEL7 by no later than November 30, 2020 in order to meet OCIO mandated security requirements. To minimize ECS system and ingest downtime for upgrading the Production servers, new bare metal custom code application HPE Blades were procured and delivered as part of this OS upgrade to the DAACs.

Raytheon configured and delivered DELL-EMC Unity 480 arrays for each DAAC to replace the VNX5100 arrays reaching end of support on 12/31/2020. Raytheon initialized and configured the hardware and added IP addresses, user IDs, storage pools and LUNs for the PostgreSQL data and backup.

For ASDC, Raytheon provided support for Clean-up of old configurations, zones and aliases on the Brocade SAN switches dating back to the CX3 and CX4 series arrays and the IBM custom code blades. For LP DAAC, Raytheon provided support for Expansion of the DELL-EMC Unity 880 to increase the capacity for the ECOSTRESS file storage. Raytheon also reconfigured LP DAAC's NetWorker cloning and DD2500 data replication when they were been disabled due to insufficient storage space on ASDC's DD2500. When NSIDC acquired the larger UNITY 880 RAID to replace the older hardware, Raytheon migrated data to the new equipment and updated the associated documentation. In addition to the new RAID, Raytheon also installed and configured NSIDC's new cross-DAAC backup hardware (EMC Data Domain 6900), to enable larger amounts of data to be stored offset in a timelier manner across the ECS project locations. This included updating the DD6900 system and configuring two-way cross site replication. Raytheon also configured Networker back-up software to use the new DD6900 onsite and replicate to GSFC.

Raytheon delivered a complete deployment of the LZARDS Non-Production (SIT and UAT) environments in the GSFC Building 32, C101 Computer Room. Raytheon documented all application and system interconnections, protocols, network ports, internal accesses, and external ingress and egress data access points, which was required in order to include LZARDS in the ESDIS System Security Plan (SSP). Raytheon also performed a series of performance tests with the LZARDS SIT and UAT hardware, in order to validate and specify the hardware components required for the future LZARDS Production environment.

Raytheon began implementing the work required to expand the current Commercial Smallsat Data Acquisition Program (CSDAP) architecture in order to handle the long-term archive and distribution of CSDAP data. Raytheon provided guidance on the cost model and cost phasing plan, resulting in a successful inflation of the CSDAP Cumulus accounts in the NGAP AWS platform. Raytheon also coached the external CSDAP team on deploying and configuring Cumulus to their account, resulting in successful ingestion of Planet data into the User Acceptance Test environment. This represented the first successful ingestion of CSDAP data into the EOSDIS archive.

In support of the upcoming MOPITT reprocessing campaign data, Raytheon created MOPITT version 9 and version 109 Earth Science Data Type (ESDT) descriptor files. Raytheon also helped ASDC correct over 120 thousand unsuccessful granule metadata exports from SDPS to CMR, covering over 200 ESDTs for the MOPITT, MISR, and TES missions. In support of the IceSAT-1 mission, Raytheon provided an Extensible Stylesheet Language Transformation (XSLT)

stylesheet to help with the conversion of ECS format granule metadata to ECHO 10 format granule metadata necessary for the transition of ICESat-1 data into the Cumulus AWS Cloud environment.

In support of the ICESat-2 mission, Raytheon provided ISO 19115 collection and granule metadata examples of Additional Attributes to help ICESat-2 personnel include more data classification information in their metadata. Finally, Raytheon updated the HEG software to provide data access services for the Level 3B Gridded Monthly Sea Ice Freeboard (ATL20) data product. Raytheon also provided HEG software updates in support of the MODIS and VIIRS missions.

Raytheon supported the NSIDC Cloud Migration, working to create a sustainable Cloud infrastructure and providing cloud availability to the ICESat-2 Early Adopter Science Group for ICESat-2 ATL03, ATL06 and ATL08 version 4 products. Part of this process involved adding a new XML transform lambda function to support ECS to ECHO10 metadata generation and allows for inclusion of checksums, file sizes and other file-related data for multi-file granules. Raytheon also leveraged the Cumulus Ingest Staging System (CISS) for automated data ingest from the current NSIDC archive and effectively provided NSIDC with an SDPS / ECS managed backup for the Cloud Data.

Raytheon conducted a technology refresh and capacity increase for each ECS DAAC. This included a 550 TB capacity increase at LP DAAC for the ECOSTRESS mission.

Raytheon conducted the Amazon Web Service Direct Broadcast (AWS DB) Study, which included leveraging the AWS Ground Station service to demonstrate an architecture that acquires, processes, and makes available open broadcast science data entirely in the cloud to determine the utility of using AWS services to respond to hazards and disasters on-demand. Due to this effort, Raytheon reduced the initial latency measured for product generation, improving, and reducing it by 60% for Level 1 and Level 2 products combined. This pilot focused on the VIIRS instrument on Suomi-NPP and JPSS-1 satellites with a secondary focus on MODIS data from NASA's Aqua.

A detailed report of activities completed under this task can found in the Task 62 Final Task Report (EED2-FTR-062), dated 8/30/2020.

Task 63 – Earthdata

Under this task, Raytheon provided major upgrades to the Earthdata software, including upgrading the Ruby version to 3.0.1 and Rails 6.0.1 for all Ruby on Rails Earthdata applications. Raytheon improved test coverage (>80) and updated FBM security headers to improve compatibility with new security protocols at some of the DAACs. Raytheon improved the Conduit Content Management System (CMS) and the Earthdata website by redesigning a major portion of the Earthdata website based on the ESDIS HQ recommendations.

Raytheon implemented Federated access token sharing among applications for Earthdata Login (EDL) and streamlined the data access workflow for cloud-based services. Raytheon modified the format of the most used Oauth tokens to JSON Web tokens to support long term token access. Raytheon developed and deployed a contingency application, the “Earthdata Login Cloud-Hosted Contingency Site,” with limited functionality in the cloud that will allow end users to download data in case of a sustained EDL outage.

Raytheon delivered a 99.81% uptime for EDL, 99.96% uptime for Earthdata Code Collaborative (ECC), and 99.98% uptime for CMS, and a 99.97% uptime for the main Earthdata site. Raytheon improved the overall architecture of the EDL to better align with cloud services and increased performance by implementing “self-signed” JSON Web tokens (JWT) in Operations and extending

the token lifetime to 90 days. Additionally, Raytheon added 39 new applications to Earthdata Login in the Operations environment and 29 applications in the User Acceptance Test (UAT) environment. EDL added 152,685 new users in Period 11 and served over 974 million requests.

Raytheon planned and executed Phases II and III of the Earthdata on premise hardware refresh of compute, storage, firewalls, and core network devices with minimal downtime. This improved the performance of all benchmarked workloads by at least 100% for computing and storage throughput without any application modifications, significantly improved the security posture of the platform, provided more comfortable room for scalability, improved fault tolerance, and completed the five-year cycle of hardware technology refresh until 2025.

A detailed report of activities completed under this task can found in the Task 63 Final Task Report (EED2-FTR-063), dated 8/30/2020.

Task 64 – Cumulus Development and Operations

Under Task 64, Raytheon developed a prototype of Cumulus integration with Azure, and added a LZARDS notification workflow step to provide integration with LZARDS. Raytheon also configured Cumulus to support TEA as a separate module so that DAACs could utilize their own TEA deployment and upgrade TEA independently of Cumulus. Raytheon implemented a scalable bulk re-ingest workflow that integrated with Cloud Metrics, allowing operators to handle re-ingesting large groups of granules more easily without impacting forward processing.

In support of NISAR, Raytheon added the ability to mark a granule as “offline,” allowing DAACs to control the visibility of granules in the CMR. Raytheon also built internal reconciliation reports into the Cumulus Dashboard, including a “Granule Not Found” report.

Raytheon completed Phase 1 of migration to Amazon RDS (PostgreSQL), including data migration and parallel writes to an RDS PostgreSQL database, resulting in the ability to rapidly disable dispensing of S3 credentials in order to allow DAAC users to limit access to data when necessary.

Raytheon continued Cloud Based Metrics integration efforts for EDC Tenants with support to twelve production applications, including eight DAAC Cumulus deployments and four custom integrations for GITC, Giovanni, Harmony, and OPeNDAP. Cloud Metrics record holdings have grown by over 500% under Task 64, with a current total volume of over 7 billion records as of July 20, 2021.

Raytheon implemented a scheduled reporting feature, whereby DAAC and application owners could request recurring automated delivery of visualizations and dashboards on a schedule they define. In support of the SWOT mission, Raytheon also refined the mission-data latency metrics to more accurately capture time to ingest new granules.

In order to improve mission data ingest and distribution accuracy, Raytheon coordinated with GES DISC and NSIDC to use controlled datasets and assessment windows and demonstrated that Kibana visualizations were within 0.01% as compared to the control and well within the target 10% established by ESDIS.

A detailed report of activities completed under this task can found in the Task 64 Final Task Report (EED2-FTR-064), dated 8/30/2020.

Task 65 – Common Metadata Repository

Under this task, Raytheon implemented a second layer of backup redundancy (in addition to the system of backups in the AWS cloud environment); on demand and once per quarter, the metadata contained in the Production-environment CMR is now backed up to a secure on premise server. Once per quarter, Raytheon also tested the restoration of the CMR metadata from this backup source.

Raytheon built the Virtual Directory interface, a navigable web interface for browsing collection and granule metadata. This directory presents CMR metadata in an architecture that is human-readable, allowing users to browse through collection metadata by temporal facets (year, month, and day) or spatial facets (cycle, pass, and tile) to find a relevant granule.

Raytheon updated the CMR-STAC endpoint to add compatibility with STAC Browser. Raytheon also built a separate STAC endpoint for browsing only the metadata belonging to cloud-hosted collections and granules. Raytheon worked toward an ingest-free bulk granule update capability by releasing functionality that allows users to add or update S3 data access and OPeNDAP links within their granules without needing to delete, reprocess, and re-ingest these granules.

Raytheon added code coverage metrics and traceability to CMR Core, OpenSearch, STAC, and Virtual Directories. This code coverage reporting is critical for ensuring that the CMR codebase is well-served with unit and integration tests.

In support of NASA's technology infusion initiative, Raytheon developed a proof of concept integration of the GCMD Keyword Recommender (GKR) with the MMT. Raytheon also stood up a Metadata Tools NGAP account to begin the transfer of the GKR from NASA-IMPACT to EED-2 and complete the infusion of this technology. Furthermore, Raytheon added support for Collection-Tool associations in the MMT.

In support of the broader Earth Science community, Raytheon conducted pathfinder testing of the MMT-GKR proof of concept integration with PO.DAAC, developed the GCMD Keyword Viewer, and prepared and initiated an ESO review of the NOAA TPIO Atmospheric Science Data Keywords. Raytheon also updated the CMR Metadata Curation Dashboard to improve metadata load speed performance and to support ingest and review of ISO-19115 collection metadata, allowing the ARC team to provide quality assurance of 1,027 existing NSIDC collections and any future collections from providers.

A detailed report of activities completed under this task can found in the Task 65 Final Task Report (EED2-FTR-065), dated 8/30/2020.

Task 66 – Sentinel Gateway

Under Task 66, Raytheon successfully acquired and distributed Sentinel-3B reprocessed products from the ESA Open Access Hub, resolved NSG operational issues, and addressed an IP address change of the ESA Open Access Hub to ensure no service interruption in NSG operations. Raytheon released NSG Version 4.8, which allowed the ingest of Sentinel data products from ESA Data Hubs following the redirected granule URIs, Version 4.9, which allowed latency tracking by Sentinel mission and data type (including ESA latency, NSG latency, PDR latency, and total latencies), and Version 4.10, which provided the capability to utilize the ESA-provided *OData API* to pull Sentinel data in the order of publication times.

In late December, 2020, when the ESA made an unannounced change to their S5P query responses to use re-directed URIs for the granules, Raytheon implemented a workaround procedure on

12/22/20 to allow NSG to continue downloading S5P data over the holidays. Subsequently, Raytheon fixed the NSG application code to correctly handle the redirected URIs to download S5P data, and the code was deployed to Production on 1/11/21. As a proactive measure, Raytheon also extended the code fix to cover Sentinel-1 and Sentinel-3 data products as well.

Raytheon resolved an incident in February 2021 where NSG experienced a slowdown in acquiring data from Inthub that had resulted in an eight-day Sentinel-1 data backlog caused by a series of ESA's maintenance activities on Inthub. To catch up with the backlog, Raytheon implemented the workaround procedure identified during the prior issue in December 2020, and reconfigured the NSG application to take advantage of the additional concurrent connections allocated by ESA support in order to work off the backlog.

Raytheon met with the NASA Harmonized Landsat Sentinel-2 (HLS) product team to exchange technical information and help the HLS team improve their data throughput in acquiring Sentinel-2 data products from ESA Inthub. Raytheon also made initial preparation of the NSG core application source code so it would be suitable for open sourcing, and submitted the necessary paperwork for both Raytheon and NASA to review the open source request.

When the ESA published Sentinel-3B SLSTR Level-1 SL_1_RBT reprocessed data products on their Open Access Hub covering the sensing period from 5/9/2018 through 2/16/2020 (a total of 306,688 granules), Raytheon set up the reprocessed data streams separately and acquired them in a controlled manner based on the data load and available bandwidth. This allowed the successful acquisition and distribution of all re-processed products without issues.

A detailed report of activities completed under this task can found in the Task 66 Final Task Report (EED2-FTR-066), dated 8/30/2020.

Task 68 – SAFe for ESDIS

Under Task 68, Raytheon submitted a white paper to ESDIS detailing how to evolve the ESDIS SAFe implementation, which was based on the SAFe 4.1 framework, to the SAFe 5.0 framework. As proposed in the SAFe 5.0 white paper, Raytheon established the basic framework for Lean Portfolio Management by working with select representatives to kick off two critical legs of governance: strategic and operational. Raytheon held the first strategic session in May, 2021; it consisted of a first-ever presentation of both the Portfolio and Train level roadmaps. For the operational leg, Raytheon created a template for the organization to use to define Portfolio Epics (large initiatives across EOSDIS) and designed a Portfolio Kanban board to visualize how many major initiatives are in flight at any point in time.

Raytheon completed the SAFe Value Stream Mapping workshop conducted by an external Raytheon SAFe expert, briefed ESDIS and the DAAC Managers regarding the proposed changes and then ultimately got approval to roll out the changes. The effort resulted in the reallocation of the original three SAFe trains into a new four-train structure: Platform, Ingest and Archive, Search and Discovery, and Transformation.

In addition to the Lean Portfolio Management, Raytheon also began providing SAFe 5.0 training for new team members, and developing a refresher training plan for existing teams or members. Raytheon designed and implemented a SAFe training plan for all four trains which covers three certification courses: SAFe for Teams, Product Owner / Product Manager (POPM), and Scrum Master.

A detailed report of activities completed under this task can found in the Task 68 Final Task Report (EED2-FTR-068), dated 8/30/2020.

Task 69 – NASA-Compliant General Application Platform

Under Task 69, Raytheon completed NGAP's roll-out of egress throttling to all EDC Tenant publicly exposed application endpoints, preventing cost overruns from unanticipated spikes in egress. Raytheon also integrated new functionality within the CloudTamer application for cloud cost savings opportunities, continually monitoring cloud resource inventory and related expenses to provide recommendations for right-sizing resources.

Raytheon delivered new capabilities to the DAACs, including a key in-region S3 access permissions update, allowing DAAC operators to grant customized, fine-grained, folder-level permissions to tenants. As part of the Data Analytics Surge initiative, Raytheon prototyped cross-application data analytics opportunities, using the Atlassian suite of software development lifecycle management tools, and cyber security and vulnerability analysis tools such as Snyk, ZAP, PSHTT, and Cloud Custodian. Raytheon also enhanced in-account DNS service by migrating from the legacy EC-2 based solution to a server-less containerized Fargate hosted solution, improving both performance and stability for EDC tenants.

Raytheon supported the ORNL and NISAR missions by enhancing Amazon Web Services (AWS) CloudFront-based egress mechanisms to support large (20GB+) file egress as needed for mission data egress. In support of CSDAP, Raytheon enhanced authentication initiatives with AWS Cognito, performing rapid service evaluation and approval and providing security baseline guidance to EDC tenants. Raytheon also integrated the new AWS Access Analyzer feature into suite of NGAP Platform services to provide continuous monitoring of IAM and S3 bucket policies.

In adherence with NASA DDI policy and the EDC Route 53 usage agreement, Raytheon developed mechanisms to collect, aggregate, and report on cloud-provisioned TLS certificates using the Platform Monitoring data analytics service. Raytheon also introduced automated TLS certificate monitoring and alerting, and automated certificate renewal processes to ensure uninterrupted HTTPS service for EDC tenant applications.

Raytheon automated the process of expiring old (90+ days) NGAP-Managed AMIs, allowing unattended compliance with ESDIS Security AMI policy, and completed the annual cyber security assessment and renewal of the Authority to Operate for the Earthdata Cloud in January, 2021.

Raytheon helped evolve the Earthdata Cloud for NASA science mission excellence by piloting an extension to the Cumulus application to leverage Microsoft Azure as a secondary Cloud Service Provider (CSP) for ingest, processing, and distribution of mission data. Raytheon also successfully piloted a novel Platform service deployment model via the AWS Service Catalog that allows EDC Tenants to self-initiate deployment of NGAP-Managed components while providing management and reporting functionality for ensuring proper patch management and security updates.

A detailed report of activities completed under this task can found in the Task 69 Final Task Report (EED2-FTR-069), dated 8/30/2020.