Final Report to the National Science Foundation Business and Operations Advisory Committee on Cost Surveillance Policy and Procedures

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Prepared By:
Cost Surveillance Policy and Procedures Subcommittee

Neil F. Albert
Mark Davis
Dr. Debra L. Emmons
E.J. (Ned) Holland, Jr.
Ronald Lutha
Kim Moreland
William G. Roets II

Subcommittee Report to National Science Foundation - Business and Operations Advisory Committee on Cost Surveillance Policy and Procedures

I. Charge of the Subcommittee

The National Science Foundation (NSF) initiated the formation and operation of an ad hoc Subcommittee of the NSF Business and Operations Advisory Committee (BOAC) on End-to-End Cost Surveillance.

The purpose of the Subcommittee is to issue a report to the Committee that fully evaluates NSF's strengthened "end-to-end cost surveillance policies and procedures" for Major Facility projects (i.e., Large Facilities).

In accordance with the charge, the report was intended to specifically state whether the Subcommittee feels the strengthened policies and procedures are sufficient to ensure compliance with their intent and application as well as the improvement and use of cost estimating/analysis and surveillance procedures within the NSF. The report includes recommendations to NSF for further improvement depending on the outcome. The review pertains to design, construction and operations awards. See Summary Section V.

Specifically, the Subcommittee reviewed and evaluated NSF's current oversight framework relating to Large Facility costs including the following: (1) cost analysis of recipient's proposal cost estimates; (2) independent cost estimate/analysis of those recipient estimates; (3) performance monitoring (earned value management) and (4) post-award cost assessments (incurred cost). Although not specifically included in the charge documents, the subcommittee also found value in review of the Program's Internal Management Plans. Figure 1 shows the Lifecycle Stages for each project as well as the Award process flow. Figure 2 provides the anticipated timeframe for the cost analysis process as well as what organization has the responsibility for performing cost analysis requirements within NSF.

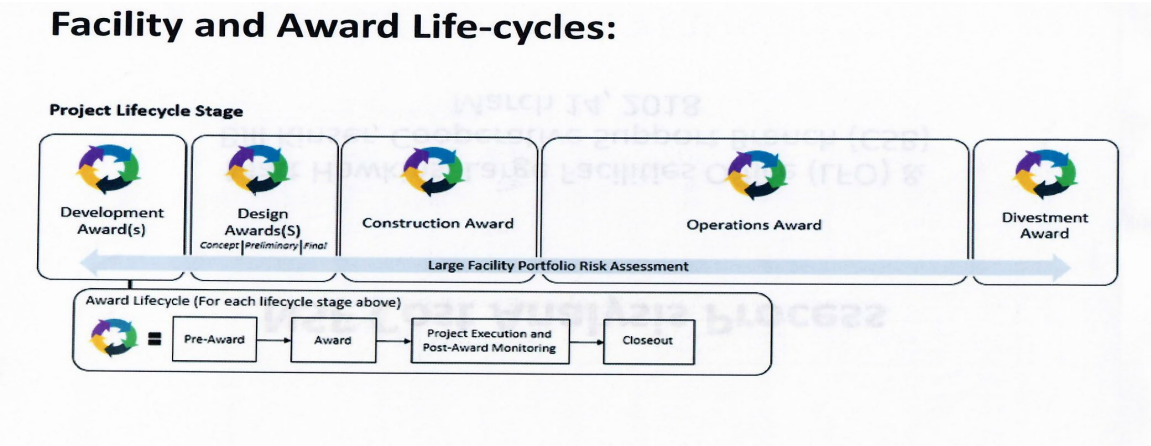

Figure 1: Project Lifecycle Stages – Award Phases

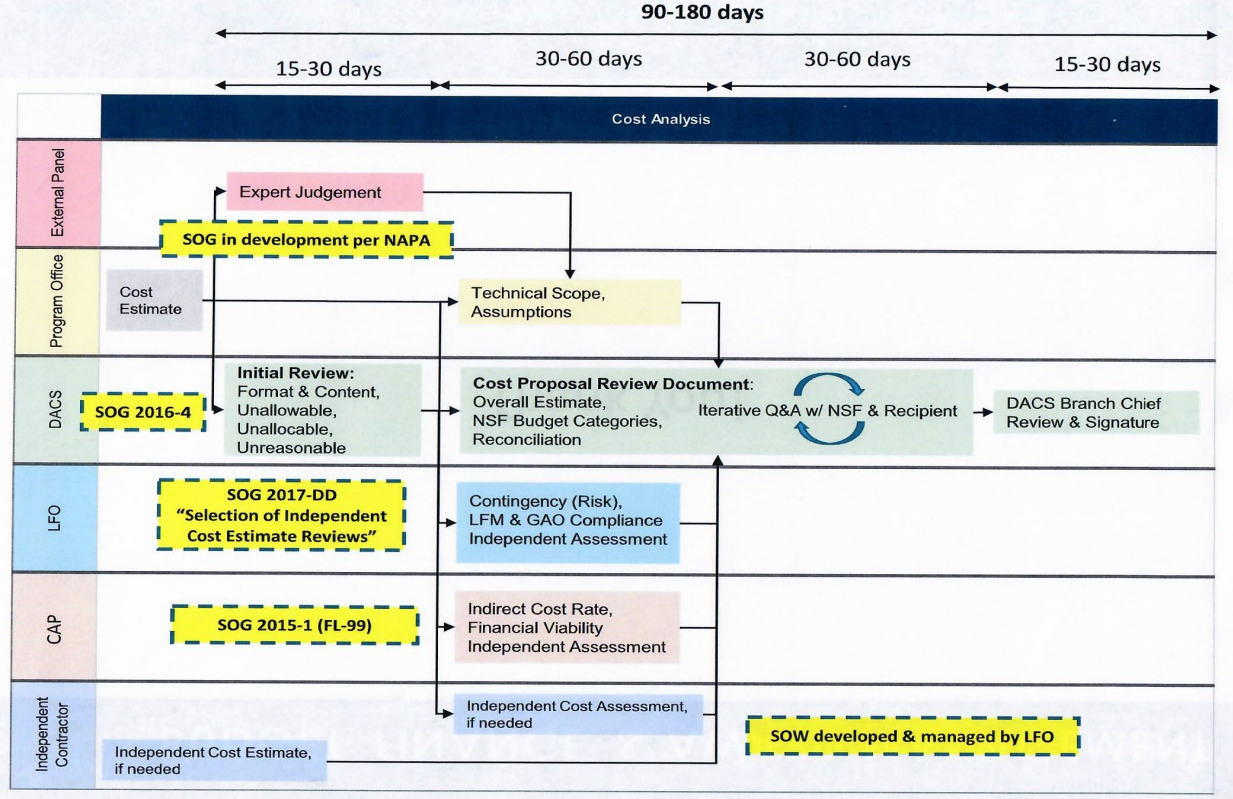

Figure 2: Cost Analysis Process Flow

II. Participants in the Study

Neil F. Albert – President/CEO of NFA Consulting, LLC. (Study Lead) (Cost Estimating)

Specializes in cost estimating, financial analysis, acquisition/program management, project performance management, and risk assessment; consulted for a broad array of government and industry organizations; recognized for contributions to the GAO Cost Estimating and Assessment Guide, DoD Standard for Work Breakdown Structures (WBS), Project Management Institute (PMI) Earned Value Management (EVM) Practice Standard, and the Society of International Organizations (ISO) WBS Standard, EVM Standard, and Program Management Standard.

Mark Davis – Partner, Education, Non-Profits and Commercial Services at Attain, LLC. (Incurred Cost)

Specializes in federal cost policy, reimbursement, and regulatory compliance, finance and grants operations improvement, strategic project outsourcing, and information technology applications, and reporting. He is a certified Government Financial Manager.

Dr. Debra L. Emmons – Assistant General Manager, Strategic Assessments & Studies Division, Civil Systems Group, The Aerospace Corporation (Independent Cost Estimate/Independent Cost Assessment)

Specializes in systems engineering, technical analysis, acquisition, program management, and strategic studies for NASA and Civil Space Programs; as well as developing and managing programs across all the NASA Science & Technology focused centers and universities and non-profit entities. Also manages the Programmatic & Technical Assessment Center of Excellence (COE) for strategic studies and analysis.

E.J. ("Ned") Holland, Jr. - Retired Assistant Secretary for Administration, U.S. Department of Health and Human Services (Independent Cost Estimate/ Independent Cost Assessment)

Specializes in human capital management, executive compensation, change management, and organizational design, which gives him a broad view of business, the ability to identify organizational issues, and insight into structure solutions and frameworks for executing tactical action plans.

Ronald Lutha – Project Director, U.S. Department of Energy (Earned Value Management)

Responsible for federal project management for the execution of projects through cooperative agreements, obtaining Critical Decision 1 (Approve Alternative Selection and Cost Range), Critical Decision 2 (Approve Project Baseline) and Critical Decision 3 (Approve Start of Construction); assisted in the development of the Environmental Assessments; work closely with DOE Office of Nuclear Physics program and provide close oversight of the project construction status; and developing and implementing organizational strategies, objectives, and action plans.

Kim Moreland - Associate Vice Chancellor, Director University of Wisconsin – Madison (Cost Incurred)

Responsible for leadership of all grants and contracts management activities at the University of Wisconsin – Madison, including proposal review and submission, contract negotiations, award set up and interpretation, accounting and financial reporting, F&A proposal and negotiation, closeout and audit. Member of the Board of Directors of the Council on Governmental Relations and served as chair of the Costing Policies Committee, also on the Board of the Federal Demonstration Partnership and serves as chair of the Finance Committee. Former president of the National Council of University Research Administrators.

William G. Roets II – Deputy Assistant Administrator for Procurement (SES), National Aeronautics and Space Administration (NASA) Headquarters (Cost Estimating)

Responsible for providing executive senior leadership and direction to the Office of Procurement by planning, coordinating, reviewing, evaluating, and ensuring the timeliness and effectiveness of the full spectrum of NASA procurement activities. Served as Director of the Contract and Grant Policy Division at the NASA Headquarters Office of

Procurement where he directed the development of NASA procurement policies and procedures and oversaw Agency-wide contract pricing procedures and strategies.

III. Background and Status of Programs Assessed

The BOAC Subcommittee assessed four projects using products and documents from across the projects' respective lifecycle stages; namely Design, Construction and Operations. Interviews were also conducted to ensure a clear understanding of the projects and the actions taken, specifically related to the Subcommittee charge. The four projects evaluated were:

A. The Antarctic Infrastructure Modernization for Science project (AIMS)

The AIMS project is currently in the final design phase. It was initially managed by the Geosciences/Office of Polar Programs Antarctic Infrastructure and Logistics (GEO/OPP AIL) Section as the primary activity lead, but the actual design, construction, and project management is provided by Leidos Corporation (formerly Lockheed Martin Corporation) as the current awardee of the NSF Antarctic Support Contract (LEIDOS). The LEIDOS contract was awarded in December 2011 and they currently are the Antarctic Support Contractor (ASC). The Conceptual Design Review (CDR) (Cost Analysis #1) was completed in March 2015 and the Preliminary Design Review (PDR) (Cost Analysis #2) was completed in December 2016. The AIMS project is expected to submit a listing of activities for the development of the final design review in October 2018.

B. Regional Class Research Vessel (RCRV)

In 2001, the Federal Ocean Facilities group came to an agreement that the Navy would support larger research vessels, and NSF would build up to three smaller, regional class research vessels. The solicitation for those three vessels was issued in 2012, and Oregon State University (OSU) has now received a cooperative agreement to build two vessels. There will likely be a third vessel authorized as well. While OSU is very experienced in operating research ships, there is not that same history with construction. Accordingly, OSU has issued a contract to a shipyard for a sizeable portion of the total amount of the first cooperative agreement for the construction of the first vessel. The RCRV project is now in the construction stage of the cooperative agreement that was effective on July 1, 2017 with an expiration date of September 30, 2023. The project had passed many of the early design phase milestones prior to the NSF's strengthened cost oversight procedures.

C. Large Synoptic Survey Telescope (LSST)

The National Science Foundation (NSF) is the lead agency and principal funding source for the LSST project; through this award NSF is responsible for the site, the building and all physical plant, the telescope and all supporting infrastructure, the data management, transport, archiving and delivery systems, and the Education and Public Outreach (EPO) program. The DOE Office of High Energy Physics is providing the camera for LSST and will support its installation, maintenance, and future operations. The Association of

Universities for Research in Astronomy (AURA) is responsible for accomplishing the project objectives and managing the project throughout construction and commissioning. AURA will coordinate communications with all associated organizations, international organizations and governments, and the scientific and engineering communities. The Stanford Linear Accelerator Center (SLAC) National Accelerator Laboratory is responsible for managing the LSST Camera Major Item of Equipment fabrication project for the DOE, and for coordinating with AURA to ensure the successful integration of the LSST system. Since LSST was in later Construction phase the project passed through early milestones prior to the cost strengthened oversight, except for budget contingency.

D. Gemini Observatory (Gemini)

The Gemini Observatory is an international partnership that operates two large-aperture (8 m) telescopes in Hawaii and Chile. Operation of the observatory is a collaborative effort (using a Cooperative Agreement) between the United States, Canada, Argentina, Brazil, and Chile; other nations also take part as limited-term collaborators. A Cooperative Agreement (CA) was signed January 1, 2017 with an expiration date of December 31, 2022. The purpose of the CA is for the Management and Operations of the Gemini Observatory. The recipient is Association of Universities for Research in Astronomy, Inc. (AURA). Since Gemini was in the Management and Operations phase, the project passed through early milestones prior to the strengthened cost oversight.

The Subcommittee was provided several thousand pages of materials. These materials ranged from guidance documents (e.g. Standard Operating Guidance (SOGs)), to project documents, to new policies. Many of these products and guidance documents were generated by NSF in direct response to American Innovation and Competitiveness Act (AICA) and Government Accountability Office (GAO) reviews that called for strengthened oversight. The NSF should be commended for its efforts to redress identified deficiencies in its project management and oversight of Major Facilities projects.

IV. Review of Process Sufficiency

A. Antarctic Infrastructure Modernization for Science (AIMS)

1) Cost Estimating

The AIMS program is currently in the Final Design phase as it was executed through a sole-source modification to the Leidos Antarctic support contract. Since this was a contract rather than a cooperative agreement, using SOG 2016-4 was not required. However, in order to perform a good cost analysis and estimate on the ASC deliverable, some level of review and analysis would be appropriate to determine if the costs were reasonable and supportable. After reviewing the Cost Analysis Memorandum for the Preliminary Design Review (Feb 2017), we found that the NSF evaluators did not sufficiently document the analysis they performed. Even though SOG 2016-4 was not required, much could have been learned from the intent of the SOG. Specifically, as a good practice, a documented estimate assessment would be accomplished to validate ASC's level of cost realism and risk for the work to be accomplished. As a result, we could not find the support needed on the evaluation of the ASC proposal. If any documented assessment was completed by the evaluators, in order to justify their conclusions of ASC's proposal, we did not see it.

Nearly all evaluations of the ASC estimates were considered "comprehensive, accurate, and credible" by the NSF evaluators. This gave the estimate a level of optimism that was not justified due to the lack of documentation by NSF evaluators of the costs anticipated. Except for issues with assumptions, clarifications of risk, staff positions, minor differences in interpretation, etc. justification was not provided as to why the estimates were "comprehensive, accurate and credible".

However, estimates such as direct labor, subcontract costs, infrastructure, facilities, etc. were based on current and historical labor rates, factors, and usage rates. For direct labor, using historical rates may be appropriate on behalf of ASC. Yet the review team did not appear to validate whether the hours applied for direct labor were assessed for realism for the next phase of the project. Subcontractor rates were based on a mix of multiple methodologies, but without a documented review of these methodologies and how they were applied, we have little confidence in the government assessment and conclusion.

ASC applied rates and factors to utilities and facilities based on current types of labor expectations. In addition, ASC brought in an independent company to provide many of these estimates. Again, we saw no evidence that any assessment as to the assumptions applied, ground rules used and estimating techniques for each element of cost were evaluated for applicability.

Recognizing the lack of documentation of the evaluator's assessment, and consideration for providing a reasonable approach for assessing this information, we found that the evaluators tried to follow a formal cost analysis review process, but without documentation, it was not supportable.

2) Independent Cost Estimate/Independent Cost Assessment (ICE/ICA)

The current NSF policy indicates that… "NSF will obtain an independent cost assessment (ICA) of large facility projects, in accordance with LFO Standard Operating Guidance, and the results of the independent assessment will be included in the Cost Proposal Review Document (CPRD) analysis. To ensure maximum usefulness of the ICA, it will be generally obtained prior to CPRD Approval #2 to ensure that analysis from the assessment is available for feedback to the awardee prior to Final Design Review."

An Independent Cost Estimate (ICE) and Reasonableness Review are required to be reconciled with the Recipient estimate during the NSF cost analysis, prior to making an award to the Recipient for construction. An ICA could be used in lieu of a Reasonableness Review since it, by definition, encompasses a Reasonableness Review.

It is important to note that an ICA is not a cost estimate; it is an assessment of the project's existing cost estimates and the documentation and practices used to generate them. In contrast, an ICE is derived by an independent party using the same detailed technical information as the Recipient (or Project) estimate. The technical information typically includes the technical baseline description; i.e., a clear definition of the

project's scope and the selected technical approach in sufficient detail to enable a credible cost estimate. Technical information also usually includes requirements, drawings, specifications, key assumptions, WBS, any high-level schedule constraints, overall acquisition strategy, and descriptions of system design, technology, and operations.

The AIMS project evolved through key milestones as part of the Design Phase:

- April 2014 - AIMS gained approval for Concept Design Review
- March 2015 – NSF Analysis #1 – Concept Design Review
- Dec 2016 – NSF Analysis #2 – Preliminary Design Review (PDR)

NSF commissioned Kforce Government Solutions, Inc. (KGS), to perform an ICA at the 15% design point in time, and then the 35% design point in time. Our committee reviewed the ICA document, but an ICE had not yet been conducted.

The KGS ICA provides an independent review of the construction, and construction support, cost estimates provided by Leidos for the Antarctic Infrastructure Modernization for Science (AIMS) project.

The ICA does an adequate role of identifying the optimism in the point design, and critical issue that needs to be addressed in contingency development and risk analysis. However, in the important conclusion areas about the baseline cost estimate, it is contradictory in nature. It states… "The very small probability that costs will occur at the Baseline level ($246.9M) implies an optimism in the point cost estimates included in the Monte Carlo simulation that has not generally been observed in other large facility cost estimates, subject to ICA analyses." yet simultaneously also concludes, we "would conclude that the Project Baseline Cost Estimate is credible."

3) Internal Management Plans and Earned Value Management

The AIMS project is being overseen by the GEO/OPP AIL Section as the primary activity lead, but the actual design, construction, and project management will be provided by Leidos Corporation (formerly Lockheed Martin Corporation) as the current recipient of the NSF Antarctic Support Contract (LEIDOS). The LEIDOS contract was awarded in December 2011. The AIMS project is in the final design phase with the submission of activities for the development of the final design review in October 2018.

In order to better understand the how the EVM process is applied at NSF, we reviewed the Internal Management Plan (IMP). A draft IMP for the AIMS project was developed highlighting the NSF organizational structure to provide oversight of the project. Since the IMP is the primary document that describes how NSF will oversee a facility through the various life cycle stages and is regarded as a living document that will be updated as the project matures, we felt that using the IMP was essential to our review process for two reasons, the IMP:

- defines in specific detail how NSF will conduct oversight of a project, and
- provides budgetary estimates for developing, construction and operating the facility, identifies divestment liabilities, and lays out a strategy for financing these

activities as well as the associated NSF oversight reporting requirements, including:

- Monthly financial reports, which include Earned Value Management (EVM)
- Weekly summaries including design reports and design/build report
- Quarterly risk management reports.

The April 2018 AIMS monthly report, which is produced by the project, includes the status, integrated project schedule along with critical path – project or program milestones, a program summary master schedule (PSMS), financial summary and projections which included a top level EVM data table, schedule and cost variance graph, WBS sub-system level EVM data including Schedule Performance Index (SPI) and Cost Performance Index (CPI) along with variance analysis based on the thresholds of cumulative cost and schedule variance +/- $50,000 and +/- 20% and cost variance at complete +/- $50,000 and +/- 20%. The key risks are discussed in the monthly report along with the associated risk update. A program summary is also included which highlights the activities of the NSF in moving the project forward. It should be noted that the LFM requires that the baseline be established at the start of construction, however the EVM data is now being monitored by the program for the final design phase effort to be prepared for the construction stage currently scheduled for the spring of 2019.

The EVMS data is being provided during the preliminary design stage of the project which is encouraged in the EVMS SOG LFO-017-2. The development of EV data at this stage of the project will help the project be ready for a Compliance Evaluation Review (CER) during the final design phase before the award of construction funds. This is a good practice and is in line with NSF guides.

The IMP states that during construction, weekly project status reports to the program officer will be required of LEIDOS which will contain more detailed information.

The AIMS Configuration and Contingency Management Plan (CCMP), dated November 2016, is described in appendix 1 of the IMP. The AIMS CCMP defines the steps and the activities required to implement and perform configuration and contingency management. The CCMP also defines the methodology for configuration identification, configuration control and change management, configuration status accounting and configuration verification and auditing for the contract, contract requirements and delivered work products.

It appears that all the LFM requirements have been satisfied by the AIMS project team. EVM reporting has been initiated based on the funding through fiscal year 2018

4) Incurred Cost Audits, Indirect Costs and Budget Contingency

As stated previously, this is a contract, not a cooperative agreement. Because this is a contract, there are far fewer flexibilities available to the recipient. Additionally, the

Federal Acquisitions Regulations (FAR) have provisions for oversight of the contract. Currently, contracting officers receive invoices with backup data from LEIDOS on a bi-monthly basis, and they work in consultation with Program on the reasonableness of costs. There are times when costs are questioned, and additional explanation is required.

The Defense Contract Management Agency (DCMA) and Defense Contract Audit Agency (DCAA) have the responsibility for auditing and negotiating Indirect Cost rates for the project. AIMS construction, which begins in March 2019, will have a very sophisticated EVM process, including a baseline structure and verification against invoices. There are multiple projects within the construction plan, and there is a commitment for science to continue during the construction phase. There will be physical inspectors from NSF on site.

Project invoices are generated bi-monthly. The contracting officer reviews billable costs and supporting documentation. The DCAA is behind on audits, but the contracting officers should receive the audit reports on this project for FY's 2014, 2015 and 2016 in the Fall of 2018. There were no findings on the Lockheed contract for FY's 2012 and 2013; that contract was transferred to LEIDOS, which is a spin-off from Lockheed. There is little concern about allowable and allocable costs incurred because of the level of project oversight and annual audits by DCAA.

B. Regional Class Research Vessel (RCRV)

1) Cost Estimating

The RCRV CDR was completed in December 2013, the PDR was completed in August 2014 and Post FDR Pre-award CPRD was completed in June 2017. The NSF assessment for the PDR and Post PDR cost proposal activities were prior to construction and developed in line with the SOG 2016-4. Based on our review, we could not determine the validity of many of the evaluator's assessments due to lack of data available. This included assessment of inflation indices, labor rate comparisons to other systems (presumably similar or like systems), fringe rates, travel, escalation of Crewing and Shore support rate increases, etc.

Where we did see the basis of the evaluator's assessments, it was based on an undocumented single conversation with a presumed subject matter expert. We recognize subject matter experts, who are knowledgeable about certain aspects of this estimate, can provide advice and clarity on the estimates submitted. However, without documentation of the conversations with these individuals we have no basis for their assessments and conclusions that were made.

In any review, the more specifics, directly related to the estimate in question, will provide more confidence in the reviewer's evaluation efforts. Without visibility into the process of how the assessment and analysis that the evaluator took, we found little substantiation (documentation) of their conclusions.

2) Independent Cost Analysis/Independent Cost Estimate (ICA/ICE)

The RCRV project evolved through key milestones as part of the Design Phase:

- Preliminary Design Review - August 2014 -- NSF Cost Analysis #2
- Final Design Review (FDR) Nov 2016 CPRD -- -NSF Cost Analysis #3

NSF commissioned an Independent Cost Estimate (ICE), which was produced in its final form in June 2014 to align with the PDR design phase. The BOAC subcommittee assessed the ICE. The ICE was to only cover the scope of the vessel construction.

The ICE appears to do an adequate part in covering different risk-driven scenarios. However, the treatment of risk events, in general, is limited and appears to address only material and production risks during construction. In addition, historical data should be used to validate the approaches. Overall, the subcommittee believes there are areas for improvement in the ICE approach.

3) Internal Management Plans and Earned Value Management

In accordance with SOG LFO-2017-2 a review was performed by two people from NSF -- one contractor who is an Earned Value Specialist, and the other who is a Project Management Control System (PMCS) Expert. The review resulted in an EVMS Assessment Report dated January 19, 2017. The review team found that the RCRV project is positioned to, but does not yet, meet NSF requirements for EVMS verification and acceptance based on the thirty-two (32) EIA-748 guidelines. The review team identified seven (7) individual guidelines with critical findings and nine (9) individual guidelines with non-critical findings that require follow-up on the part of the project prior to NSF acceptance of RCRV's EVMS.

The EVMS Corrective Action Plan was submitted by Oregon State University (OSU) on June 29, 2017 and NSF accepted the OSU EVM system as compliant with the intent of EIA-748B. SOG 2017-2 Earned Value Management System (EVMS) dated March 2017 states that "The frequency and focus of surveillance reviews are determined by the Program Officer in consultation with the Large Facilities Office. Yearly surveillance as part of annual reviews are the norm, but a different frequency may be judged to be beneficial." According to documentation provided during the review the EVMS Surveillance Review for RCRV is planned for July 2018.

Monthly project Report #4 dated November 27, 2017 and Report #5 dated December 21, 2017 were provided to the committee. An outline of the monthly report including the EV information is stated in the Cooperative Agreement. The two reports provided during the review provided the required information from the recipient on project status, current photos, Integrated Project Schedule, Financial summary and projections, EV data with an analysis of cost and schedule variances, risk management and narrative/tracking of risks, and cost/schedule/scope contingency status. At the end of the monthly report is a Program Summary highlighting the analysis of the NSF Program Officer which should be adopted as a best practice.

The reviewed monthly project reports were found to be comprehensive and informative. Based on the extensive financial and earned value management data presented in the Monthly Project Reports, the NSF can provide, using EVM, adequate oversight of the RCRV project during the construction phase.

One concern however related to the EVM review was that the RCRV Internal Management Plan (IMP) has not been updated in the last four years. According to the Large Facilities Manual (NSF 17-066, dated March 2017) table 2.1.6 "Roles and Responsibilities for NSF Staff for Management and Oversight of Large Facilities" the IMP should be developed during the Conceptual Design stage and updated during the Preliminary Design, continues to monitor in accordance IMP during the Final Design and update the IMP during the construction/implementation stage.

4) Incurred Cost Audits, Indirect Costs and Budget Contingency

The total award to OSU is about $353 M, and of that about $230M goes to the shipyard in a contract for fabrication. NSF has negotiated a separate indirect cost rate for this project, a 2% General & Administrative rate for the contract. All of this is within current policy. There will be an incurred cost audit conducted in 2019.

Contingency funds require multiple approvals before being released. Once they are made available, they are expended in the same way as regular project funds, and they are subject to the same regulations and policies. All funds are subject to multiple layers of oversight through monthly reports, annual risk assessments, EVM reports, 3 quarterly site visits to the shipyard and 1 annual visit to OSU as well as the incurred cost audits.

The contract for actual construction was issued on a fixed price basis, with NSF approval, for the fabrication; payments are based on progress. OSU has field office staff in Louisiana who look at the invoices and compare the costs to actual progress

C. Large Synoptic Survey Telescope (LSST)

1) Cost Estimating

The LSST cost assessment effort was started prior to the release of SOG 2016-4. As a result, we were not able to evaluate the documentation.

2) Independent Cost Estimate/Independent Cost Assessment (ICE/ICA)

The LSST project evolved through key milestones as part of the design phase:

- September 2007: Prior to strengthened procedures – Cost Analysis #1 Concept Design Review September 2011: Prior to strengthened procedures – Cost Analysis #2 Preliminary Design Review
- December 2013: Cost Analysis #3 Final Design Review (FDR)

**NSF Commissioned a Sufficiency review on LSST but the BOAC subcommittee did not review the document.

3) Internal Management Plans and Earned Value Management

The effective date of the Cooperative Agreement is July 1, 2014 with an expiration date of September 30, 2022 for the construction of the Large Synoptic Survey Telescope (LSST). The recipient is Association of Universities for Research in Astronomy, Inc. (AURA).

The LSST EVMS was assessed in February 2016 by an independent review team (performed by two NSF PMCS experts and one external contractor that was an earned value specialist) in accordance with NSF draft internal standard operating guidance *Earned Value Management System (EVMS) Validation, Surveillance, and Acceptance Guide* that was in draft at the time of the review. The review team determined that the LSST EVMS is effectively implemented and the Project Team is appropriately using the associated tools and processes. Furthermore, the LSST Project Team has satisfactorily addressed the recommendations made by the review team to fully meet the intent of the EIA-748 Standard for Earned Value Management. After the project appropriately responded to the review committee recommends, NSF-LFO accepted the LSST EVMS as meeting the intent of EIA-748 on January 25, 2017.

The review committee was provided one monthly report dated November 15, 2017 as an example of monthly reports submitted to NSF by LSST. The monthly report followed a similar format as the RCRV, AIMS projects and stated in the Cooperative Agreement Section 6 "Reporting and Review Requirements." The details in the monthly report are good and informative. The EV information is appropriate along with the cost and schedule variance analysis and updated risk analysis information. The Program Summary at the end of the monthly report demonstrated NSF oversight of the project and interagency active on the project.

No Integrated Management Plan (IMP) was provided to the committee for the LSST.

4) Incurred Cost Audits, Indirect Costs and Budget Contingency

NSF is the cognizant agency for AURA, except for the NASA activities. The indirect cost proposals are reviewed annually, and indirect rates are negotiated with the NSF Cost Analysis and Pre-Award (CAP) branch. AURA has over 30 separate rates in use with each rate specific to a project and location. In addition, there is one corporate rate. There is a long-term relationship between AURA and Chile, and there is a special rate for this Chilean-based telescope. There were established rates that pre-dated the LSST project, and those rates recognized the impact on costs of Chilean labor unions. The complexities are enormous.

The AURA management fee for LSST is about $150,000/year for this very complex project, currently valued at over $600 M; the AURA administrative rate is about 2%.

The project has been subject to Accounting System Reviews, a financial viability study, business systems reviews on a schedule, regular financial reports, and an incurred cost audit.

Hamilton Enterprises, LLC, performed an Incurred Cost Audit on the LSST for the period July 1, 2014 to June 30, 2016. The audit, which followed a standard approach to incurred costs, looked at internal controls in relationship to incurred costs and to issues of allowability, allocability and reasonableness. In addition, the audit looked for instances of fraud, waste, and abuse as well as any instances of material misstatement of costs. Total costs for the period under review exceeded $90 M, and auditors questioned costs of $6,844 in fringes, $5,233 in exchange rate costs, and $7,029 in costs associated with a Chilean non-profit. Auditors also noted that LSST undercharged indirect costs in the amount of $22,177 for that same period, ending in a net of <$3,081> for the audit.

The incurred cost audit was in accordance with NSF policy. However, auditors strongly recommended that AURA switch to full accrual accounting in accordance with GAAP. NSF has also recommended that AURA make that change.

D. Gemini

1) Cost Estimating

The Gemini cost assessment effort was started prior to the release of SOG 2016-4. As a result, we were not able to evaluate the documentation.

2) Independent Cost Estimate/Independent Cost Assessment (ICE/ICA)

The Gemini project review started with the Operations Award in April 2017. Since the Operations phase is not associated with the stage gate review process, there were no independent cost estimates/analysis reviewed for the Gemini project.

3) Internal Management Plans and Earned Value Management

Quarterly and Annual reports are used to communicate efforts to maintain and improve the performance of the observatory, its telescopes and instruments, and to enhance user and stakeholder services. Reporting includes deliverables and milestones and will assess the risks associated with all major development activities at the observatory and detail the steps being taken to mitigate these risks.
Required reports include:

- Risk Management Plan
- Annual Progress Reports and Plans
- Finance Reports
- Operations and Development Reports
- Final report – within 90 days of the expiration date of the CA.

The committee was provided the 2017 Annual Progress Report of the Gemini Observatory and the 2018 Program Operations and Development Plan of the Gemini Observatory. Both documents were very detailed of the past and potential future activities at the observatory in accordance with the CA. EVMS is not required under an operating CA.

4) Incurred Cost Audits, Indirect Costs and Budget Contingency

The Gemini Observatory is an international partnership that operates two large telescopes located on the summits of Maunakea, Hawaii and Cerro Pachon, Chile. There is currently in place a 6-year, $208 million cooperative agreement to the Association of Universities for Research in Astronomy, Inc. (AURA) for the management and operation of the Gemini Observatory.

Gemini was constructed under a contract, not a cooperative agreement, but the current operations award is a cooperative agreement. Gemini participants include the U.S., Canada, Chile, Brazil, Argentina, and Korea. Astronomers in those countries and at the University of Hawaii have ongoing access to Gemini, and any astronomer in those countries can apply for time on Gemini.

Gemini is an observatory, but it is also an instrument that needs upgrades. There was a suggestion of utilizing a contingency fund, but NSF does not do contingencies for operations awards. Instead, Gemini has included a complexity factor in the budget.

The indirect cost rates, as with LSST, are negotiated between AURA and NSF CAP on an annual basis. Prior approvals are required generally as outlined in 2 CFR 200, the Uniform Guidance, and include categories such as sub awards, change in Principal Investigator, change in the scope of work, etc. Costs are monitored for allowability, allocability and reasonableness through quarterly financial reports, the indirect cost negotiations, and incurred cost audits. There is a continual emphasis on outcomes in relation to costs.

V. Summary

NSF has many policies, provisions, and practices in place to assess, support, justify modify, and monitor internal controls that support appropriate spending at the recipient organization. There is a comprehensive network of audits and reviews that provides strong and sufficient policies and procedures for large facilities projects. Among the monitoring policies, there are certain requirements that are especially noteworthy:

- The Cost Proposal Review Document (CPRD; SOG 2016-4) that contains a discussion of the recipient's cost proposal estimating reasonableness, justification of costs and overheads, use of independent estimates/analysis, and post award issues and incurred cost audits
- SOG – Selection of Independent Cost Estimate Reviews (Draft)_
- SOG – Budget Contingency
- SOG – FL 99
- Section 4.2 of the LFM
- Internal Management Plan (IMP) for construction awards the lays out a plan for post award monitoring activities including reviews and audits.
- Communication documentation to maintain and improve the performance of the program depending on the life cycle stage including:
  - Project Execution Plan (PEP)
  - Risk Management Plan and other plans
  - Annual Progress Reports
  - Finance Reports

  - Operations and Development Reports
- Accounting System Reviews, typically for new recipients, led by the Cost Analysis and Pre-award Branch (CAAR) staff.
- Business System Reviews, which can be focused or general in scope, designed to provide oversight of the people, processes, and technologies that support the administrative management of a Facility.
- Review of the status of recent recipient single audit reports or program-specific audits.
- Frequent financial and progress reports that are reviewed by advisory committees and NSF staff with a focus on the relationship of expenditures to project progress.
- Incurred cost audits based on risk or in accord with recent AICA standards that require an audit of construction awards during the life of the award and at least every three years.
- The addition of BFA 2018-YY, Minimum core competencies for Oversight and Management of Major Research Infrastructure, a SOG document. The document, developed in response to a NAPA report, establishes a set of core competency guidelines for project management expertise needed by NSF staff in various roles on the project. These core competencies, in the subcommittee's opinion, are critical to the future success of this cost analysis process. The more NSF trained analysts that apply these competencies, the better the process will be accomplished. The result will be a clearer understanding of what the requirements are to provide supportable and justifiable assessments, as well as ensure the results meet the SOGs and LFM intent.

The Subcommittee review process included evaluation of all the documents above (including the programmatic data associated with each of the four projects being assessed) as well as face-to-face interviews with NSF staff. Overall, all NSF personnel were very helpful and open about their efforts, issues and expectations they had for their recipients. It also included a detailed review of the data provided by NSF on their external SharePoint site. Each team evaluated individually the project against the policies, procedures and processes defined for their portion of the cost analysis activity (i.e., Cost Estimating, Independent Cost Estimate/Analysis, Internal Management Plans and Earned Value Management, and Incurred Cost Audits, Indirect Costs and Budget Contingency).

The subcommittee concluded that overall, the processes were followed. However, the level of rigor applied to each process varied depending on who and what was required.

Specifically, the EV requirements are stated in SOG LFO-2017-2 (Earned Value Management System Verification, Acceptance, and Surveillance, dated March 21, 2017) and the reporting requirements are stated in the Project Execution Plan (PEP). NSF's policy and procedures for verification and utilization of an Earned Value Management System (EVMS) has been appropriately implemented on the project's that were reviewed. The EVMS verification process by NSF of the recipient is beneficial since it ensures that the data is accurate and is timely reported with analysis by the Program Officer's.

The Internal Management Plan (IMP) is the primary document that describes how NSF will oversee development, construction, operation and eventually divestment and closeout (described in section 2.3.1 for MREFC and in section 2.7 for non-MREFC projects). As stated previously, an IMP was an important document for understanding on how EVM is implemented and managed. Most of the projects reviewed developed an IMP, however not all the IMPs were kept up to date

as required in the Large Facilities Manual. Keeping these documents up to date is important to ensure consistency of management application and execution.

The Cost Estimating and Independent Cost Estimate/Analysis portions of the review were not as well accomplished. For example, a key purpose of the CPRD is to document the evaluator's review, provide justification of their assessments, and support or propose changes to the recipient's proposal for award. These were not accomplished to the level that garnered confidence in their assessment and did not totally meet the intent of the CPRD. While decisions were made using this documentation, the subcommittee did not see enough detail developed to support the NSF evaluator's position with either cost estimating rigor or the use of independent cost estimates or analysis. However, based on the results, the costs approved by NSF and applied to each project seemed to be within reason for execution. While that is good, the process used did not support how their assessment justified the cost of these projects.

The NSF should be commended for doing a good job of documenting what is required and providing support to the reviewers by enabling them to keep the process moving forward to ensure basic research and science is accomplished within a wide variety of disciplines.

Given the results, the BOAC subcommittee believes **that NSF's processes are sufficient to ensure compliance with their intent and application as well as the continued improvement and use of cost estimating/analysis and surveillance procedures going forward**. At the same time, the subcommittee offers some considerations for more effective cost estimating and analysis, performance measurement and programmatic oversight in the future.

VI. Considerations for Improvement

As previously discussed, the subcommittee believes the processes are sufficient to ensure compliance with their intent and application as well as the continued improvement and use of cost estimating/analysis and surveillance procedures going forward. However, to understand these processes and procedures one must read and review a plethora of paperwork to understand the full aspects and purpose of the documentation. We recognize that each document has its own intent and use, but to review these documents individually can lead to confusion and misapplication of the requirements. Therefore, as our only overarching recommendation, NSF should consider consolidating SOGs, manuals, and other policies and procedures, as appropriate, into a single document or series of focused documents addressing "cost analysis" or at a minimum, the four major areas of our review. This would reduce the amount of paper to review and bring cohesion into the process and eliminate redundancy across multiple policies, procedures, and manuals.

The following are further considerations for improving the cost analysis process in the four major areas of review.

A. Cost Estimating

The documentation describing what is required to perform cost estimating and analysis on recipients' proposals is clearly documented in the Large Facilities Manual (LFM) NSF 17-066 (March 2017) and Standard Operating Guidance (SOG) 2016-4. While the LFM provides guidance for supporting, justifying and evaluating Recipient cost estimates; the

SOG provides the reporting format, cost analysis techniques, and evaluation criteria by which the Division of Acquisition and Cooperative Support/Cooperative Support Branch (DACS/CSB) can provide their evaluation of the recipient's cost estimates for the Conceptual, Preliminary, and Final Design Phases of the program. The Subcommittee determined that neither of these documents were followed consistently. Whether it was due to a misinterpretation of what is intended or the time available or the knowledge and training of the personnel performing the analysis, the evaluation process and its documentation was less than satisfactory. Based on the documentation it was difficult to understand how the recipient's estimate was either allowable, allocable, or reasonable. Analyses were not provided to ascertain this information.

Some considerations to improve this process are as follows:

The CPRD template is documented in the SOG. For the purpose of documenting the Proposed, Objective and Final Result of the dollars required for the recipient and NSF Program Officer's negotiation, it is relatively reasonable. However, to document the realism, reasonableness and justification the evaluator has provided of the recipient's estimate is neither considered nor supported in the document. It is up to the recipient to provide supportable evidence that the amount of dollars estimated would be reasonable and justifiable to receive the dollars required. It is the role of the evaluator to determine whether the quality and supportability of the recipient's estimate is strong enough to accept their proposed dollars. This should be accomplished whether it is a contract or a grant. In doing so the evaluator needs to show how they determined the reasonableness and by what means they used to substantiate or not, the recipient's estimate. Without this documentation by the recipient and the evaluator, it leaves speculation as to the validity of the process. It is recommended that the recipient provide a well-documented, quantitative justification and support as to how they derived the dollars and hours for each element of their proposal. In the same way, it is recommended that the evaluator provide a well-documented, quantitative justification and support as to how they substantiated the recipient's proposal or what quantitative or qualitative justification they used to change the recipient's recommendation.

What little of the recipient's justification's we were able to exam was based on one of two estimating techniques: engineering estimates (expert opinion) or engineering build-up. The engineering build-up methodology used factors, quotes, expert opinion, and estimates to support the analysis. By its nature, expert opinion is the least supportable methodology as it is based on one or many people's opinion. This is clearly documented in the GAO Cost Estimating and Assessment Guide. Yet NSF may inadvertently encourage the use of Expert Opinion since it is usually the first option when listed as a recommended approach. By the fact that it is listed first, we are assuming that the recipient could believe this is what NSF's first preference is. On the other hand, for those items that are being purchased or are based on some form of factual data, engineering build-up estimate has value – assuming the analyst has validated the information used and normalized the data to address the element being specifically estimated. It is not appropriate to use data to support an estimate without showing the relevance of the data to the estimate it supports.

It is recommended that the methodology used for estimating purposes be required in this hierarchy of preference:

- Actual/historical data for the system/subsystems being estimated,
- Analogous data (like or similar to the system/subsystem which closely represents the data being proposed) with adjustments to reflect the technical and complexity differences between the analogous and actual system/subsystem being estimated,
- Parametric data which should be used for higher level work breakdown structure estimating. This data should generically reflect the system being estimated, but modified to reflect the technical, size, weight, quantity and/or schedule of the system being estimated,
- Expert opinion which should be used only if a secondary methodology is used to substantiate the expert opinion provided by the recipient or evaluator.

The same order of methodology should be used by the recipient as well as for the NSF evaluator. Most evaluators are using their own expert opinion to justify the recipient's expert opinion. This unfortunately is a redundant approach to the process. A different methodology should always be used to substantiate/justify another estimate whether it is a recipient's estimate or an evaluator's estimate.

As a recommended improvement, use of cost analysts/estimators that are certified through qualified organizations (i.e., International Cost Estimating and Analysis Association (ICEAA) or American Association of Cost Engineering, International (AACEI)), should be encouraged. Using certified and qualified estimators provides assurance that the estimating process is followed, and best practices are applied to estimates, reviews and analyses. The SOG on "Minimum core competencies for Oversight and Management of Major Research Infrastructure" states that certification is desired. Follow through of this recommendation will greatly enhance and improve the estimating and analysis capabilities of NSF analysts. This applies to those who perform Independent Cost Estimates/Analysis.

Finally, the most compelling portion of any estimate is its documentation. It needs to tell a story, so the reader can understand the analysis and if possible, reproduce the results of the estimate. This means both the recipient and the evaluator need to be clear in their documentation of their approach, analysis and results they provide to clearly and succinctly describe their estimate. Without this, it is hard to determine the estimate is allowable, allocable, or reasonable. Whatever methodology used, it should provide the best supporting documentation available to ensure confidence in the estimate it supports

B. Independent Cost Estimates/Analysis (ICE/ICA)

In its current form, the ICA utility appears limited. It is boilerplate in nature and doesn't appear to really address the complexity of the projects, their project management and risk identification. The ICAs are useful in the initial phases as an Agency begins to strengthen its oversight and project management processes and learn how to do the programmatic oversight. Over time, the NSF should migrate to ICE products even if higher-level in nature and early in the project lifecycle. The independent cost products

need to focus on the "how of the estimating", the risk identification and evaluation, and address the "credibility" side of cost estimating. By design the ICA is focused on process, not content, and the issues at this point in NSF's oversight processes should migrate to content.

An ICE should be conducted as early as possible in the project lifecycle of the project to inform possible trades and descopes. The BOAC subcommittee expected to see an ICE product, even if preliminary, for the AIMS project.

- The ICE product should also be used to foster discussions about risks between the independent agent and the Project. It is currently unclear how the ICE products are used to drive dialogue and reconciliation around risks and assumptions.
- An independent schedule estimate (ISE) should be performed in concert with the ICE for enhanced confidence. Schedule is often a driver of cost and it should be assessed accordingly. The NSF should consider budgeting to an independent probabilistic schedule analysis.
- The traceability of non-negotiable science and or technical performance requirements is not apparent or traceable from the products. Since there is such a strong reliance on scoping (design phase) and descoping (construction phase) to meet the cost caps (see 6) below), there should be more clearly defined criteria around scoping/de-scoping decisions. Threshold or Non-negotiable requirements are the level of requirements below which the project isn't worth doing.
- NSF has implemented a "No Cost Overrun Policy" on MREFC-funded construction projects. This policy requires that the Total Project Cost (TPC) estimate developed at the Preliminary Design Stage has adequate contingency to cover all foreseeable risks, and that any cost increases not covered by contingency be accommodated by reductions in scope. However, descoping well into the implementation phases of a project has been studied and typically doesn't yield the cost savings forecasted.

The other issue with this approach is as follows. All foreseeable risks can be captured or categorized as "known-unknowns" risks. Estimated costs to cover "known-unknowns" are included in the cost contingencies. Estimating only known risks will lead to underestimating the costs, as there is uncertainty in all complex developmental projects; this discovery is understood in project management and cost estimating communities and such risks are known as "unknown-unknowns."

In summary, this "No Cost Overrun policy" is misleading, and sends a confusing message both internally to Project Managers and to Stakeholders. If the overall objective is to have Major Facilities projects which are cost-capped, then a specific process for trading off between science/technical requirements, and programmatic performance should be codified.

For additional benchmarking on policy and guidance, NASA Science Mission Directorate has made progress in two key areas which could offer additional insights to NSF project oversight, a) Research that demonstrated the reasons for cost and schedule changes on

projects, and b) budgeting policy that enables more effective portfolio project management.

Regarding a) for complex aerospace, transportation, and major facilities projects, uncertainty always surrounds the project developments. The NASA Explanation of Change study demonstrated that 1/3 of the cost change impacts were due to external project events, that is, events outside the project manager's direct control, (e.g. funding profile interruptions), 1/3 of the cost changes were due to project planning, and 1/3 of the cost changes were due to project execution. [i] Nine considerations were made with the objective to decrease the potential for cost change in future missions. [ii]

Regarding b), currently, it appears from the BOAC subcommittee assessment of the four projects that there are no additional Unallocated Future Expenses (UFE) held at the NSF Headquarters level for portfolio management across its set of Major Facilities projects. UFE is the portion of resources identified in the probabilistic calculations that cannot yet be allocated to a specific Work Breakdown Structure (WBS) sub-element as the specific risks have not been realized. Managing at portfolio level and maintaining UFE has improved programmatic performance for a large set of complex NASA science missions[iii].

C. Internal Management Plans and Earned Value Management

The Earned Value Management process has been accomplished effectively. Analysis has been completed and data is being used to better understand the recipient's performance. The recommendations for this area are:

- Continue the appropriate implementation, verification and utilization of EVMS.
- Consideration needs to be given to updating the IMP on a regular basis.

D. Incurred Cost Audits, Indirect Costs and Budget Contingency

We recommend that NSF initiate a dialogue with the recipient community in preparation for the establishment of a set of core competency recommendations for recipient staff who support the administrative and management aspects of large facilities projects. The magnitude of the awards and the tremendous complexities of the projects requires that recipients bring the necessary expertise to the management, including post award responsibilities, of any large facility activity. These projects are managed according to a host of regulatory and contractual provisions in addition to the NSF policies and procedures for operations. Those provisions may be well beyond the experience of many financial managers, and the development of competencies would reflect the skill sets necessary for the management of these projects.

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[i] "Explanation of Change (EoC) Study: Approach and Findings", Bitten, R., Emmons, D., Bordi, F., Scolese, C., IEEE Aerospace Conference, March 2013

[ii] "Explanation of Change (EoC) Study: Considerations and Implementation Challenges", Bitten, R., Emmons, D., Bordi, F., Scolese, C., Hart, M., Hinners. N., IEEE Aerospace Conference, March 2013

[iii] "The Effect of Policy Changes on NASA Science Mission Cost & Schedule Growth", Bitten, R., et. al, IEEE Aerospace Conference, March 2018