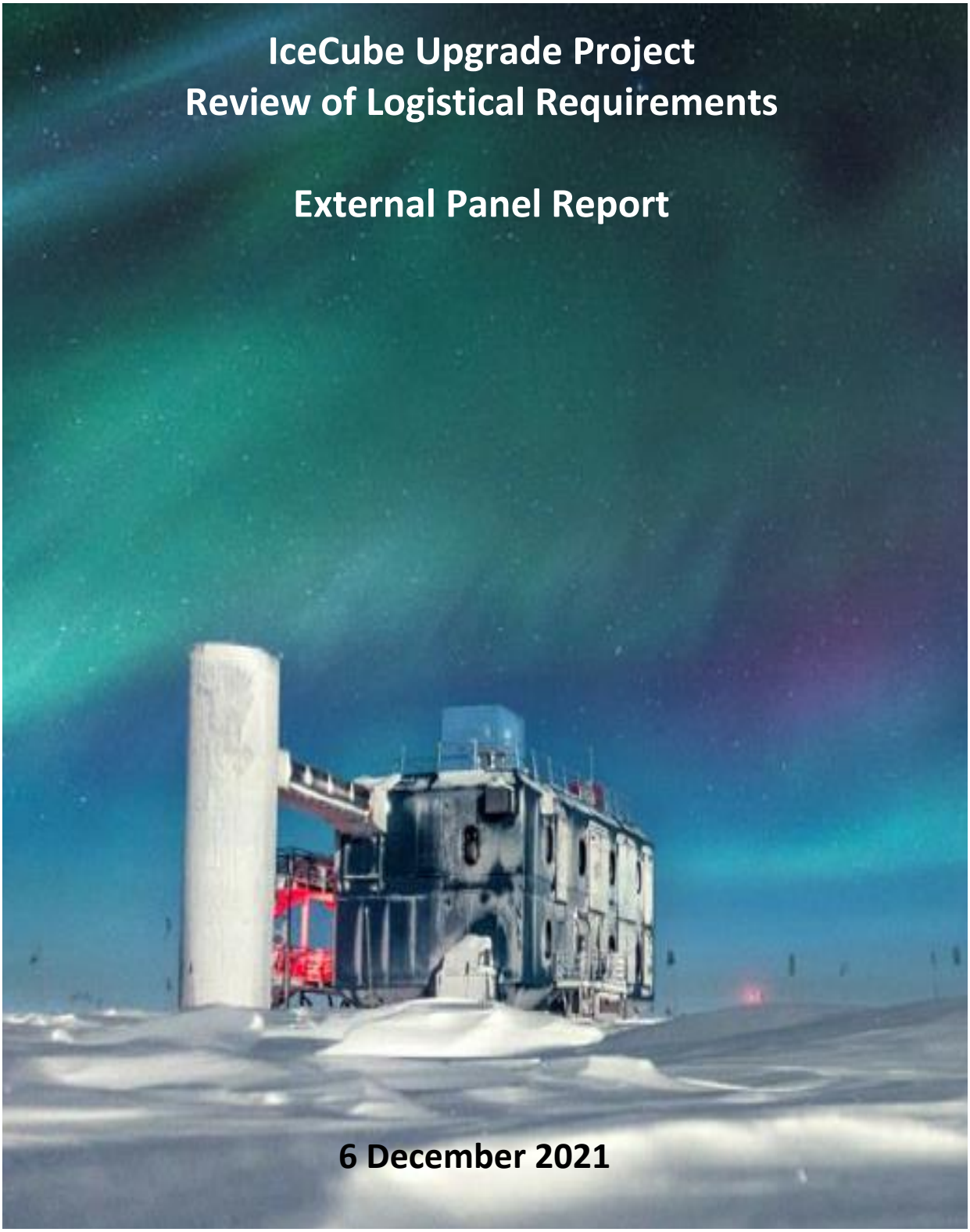
IceCube Upgrade Project
Review of Logistical Requirements

External Panel Report



6 December 2021

PREFACE

The National Science Foundation (NSF) established a panel to provide an external review of the logistical needs for the IceCube Neutrino Observatory (ICNO) upgrade (IC/U) project. ICNO and its operators are an active component of the U.S. Antarctic Program (USAP) which is managed by NSF. This panel met with NSF and IC/U project personnel 3-5 November 2021.

The ICNO, located at the Amundsen-Scott South Pole Station in Antarctica (Station), utilizes an array of surface detectors and photosensors distributed through one cubic kilometer of deep ice to observe neutrinos from astrophysical sources. ICNO has been in full operation since 2010. The IC/U project, when completed, will consist of seven new columns (or "strings") of photosensors, densely embedded near the bottom center of the existing ICNO sensor array. The Upgrade will include new calibration devices designed to enable a better understanding of the optical properties of glacial ice and the detector's response to signals from muons traversing the array. The improved calibration resulting from the Upgrade will be applied to the entire archive of IceCube data collected over the last ten years, thereby improving the angular and spatial resolution of the detected astrophysical neutrino events and facilitating ICNO's search for point sources of high energy neutrinos. The Upgrade will also provide world-leading sensitivity to neutrino oscillations and will enable unique measurements of tau neutrino properties.

The panel's charge was to examine the cargo and labor effort proposed in the Upgrade plan for fieldwork (drilling the icesheet and deploying new strings) that will be needed by the IC/U team and the methods that were used to estimate these needs. This charge took the form of ten questions grouped into three categories.

This report, and the panel's interactions and discussions during the review meetings will assist NSF and ICNO in re-planning the Upgrade's fieldwork necessitated by the COVID-19 pandemic and respective delays of all science field activities in Antarctica during the 2020-2021 and 2021/2022 austral summer seasons. NSF will conduct a re-baseline review for the Upgrade project in March 2022 that will consider the IC/U logistical needs and NSF's capabilities to support those needs as inputs for establishing a revised, risk-adjusted budget and schedule for completion.

The panel members appreciate the opportunity and privilege of interacting with the IC/U team and NSF program managers in conducting this review. We are:

Richard Armstrong | George Blaisdell (Chair) | David Gregory

Steven Theno | Jeff Zivick

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INTRODUCTION

Once formed, we (the panel) received documents from the IceCube Neutrino Observatory Upgrade (IC/U) project team. These materials covered a wide range of logistics plans in detail. The selection of materials was likely driven by the group of questions that formed NSF's charge to us and was provided to the IC/U team during the third week of October. The provided documents were reviewed by us and discussed during a 25 October video teleconference involving only NSF. We developed a list of questions during this meeting. The questions were transmitted to the IC/U team and, during a 29 October video teleconference that included the IC/U team, and they replied to those additional questions.

The first day of panel meetings (3 November) was consumed with presentations from the IC/U team. During day two, presentations continued for half of the day followed by questions from the panel. Questions to and answers from the IC/U team, including more detailed replies to some of our earlier questions, occupied the final day of meetings. At the conclusion of the meeting, we presented a summary of our initial impressions of the logistics plan for the IC/U project (Project). That summary forms the basis for this report.

FINDINGS

At the outset, we vigorously commend the Project team on their presentations and responses to our questions. The responsiveness and attitude of the Project team made the review more like a collegial collaboration not an inquisition.

Our findings are divided into four parts. The initial three are based on overall impressions and most pressing concerns. The final category presents brief answers to each of the questions associated with the NSF charge.

Project Team

Every member of the Project team with whom we interacted demonstrated an in-depth knowledge of the project and possessed very relevant experience, most from the original and DeepCore portion(s) of the IceCube experiment. This level of understanding is perhaps the most important factor for success in this project.

Having heard presentations and answers to our questions from more than a dozen Project team members, we were impressed with the teamwork demonstrated. Clearly, a common understanding exists among the team members, as well as mutual respect and collegial attitudes.

Also apparent among the Project) team is their dedication to the effort and perseverance in its achievement. Several setbacks have beset the Project, the most significant being the severe impact to the entire US Antarctic Program by the COVID-19 pandemic. We did not detect any loss of energy by team members despite the cancellation of their planned initial field season and the ambiguity of when they may be allowed to deploy.

Technical Strengths

A project with the scope and setting of IC/U is sure to fail without a clearly defined and communicated goal. Our interactions during this review indicate that the Project team

members all have a clear understanding of the goals of the Project and are in synch with each other in achieving them. The translation of goals into technical requirements for success also appears to be well defined and communicated and is apparent in the high degree of collaborative work between team members that we witnessed during the review meeting.

That the collaboration we observed appears to be both efficient and effective likely owes to the breadth and depth of experience of team members (IceCube and DeepCore). It is hard to imagine that any other project anywhere in the world could adequately prepare one for the work required to achieve the Project. With most of the planners for the Project having intimate experience with IceCube in the past represents a significant strength. Understanding the logistics and its unforgiving nature in Antarctica, especially at South Pole, is vital for Project success.

In the same vein, the Project's plan to use basically the same approach and equipment that produced IceCube is viewed by us as greatly reducing risk. It is also encouraging that the Project has reviewed and incorporated lessons learned from the earlier IceCube efforts, performed analysis on past operational activities, and found opportunities for improved performance and optimization of tasks. Similarly, the Project understood that wintering and long duration inactivity of much of their equipment in Antarctica likely impacted its functionality and reliability. In addressing this risk, we are impressed that the Project sent a field team to inspect all the drilling equipment, bringing back with them lists of replacement parts required and components that need refurbishment. This field team also, wisely, inspected the sites where the Project's activities are planned to take place, to ensure that as many unknows as possible have been removed. This included excavation to examine the cable entrance port to the IceCube Laboratory (ICL, aka Counting House).

We were especially impressed with the approach used to establish a fuel plan for the Project. Taking past IceCube drilling experience into account, using models to adjust for the difference in the holes to be drilled in the Project compared to the past, and creating reasonable contingencies, we have good confidence that the fuel budget for the Project is appropriate.

The Project, likely because of its high percentage of personnel with South Pole experience, appears to be properly seriously considering both engineering and safety challenges. There is almost nothing that can be done outdoors at South Pole that doesn't involve personal risk, or that could be considered comfortable. Having that understanding forefront when planning each activity and process in the Project is vital to achieving successful field seasons. Every detail, from the duration of work shifts, timing of warm-up breaks, tasks requiring sans-gloves dexterity, fluids handling, etc. has the potential to make or break Project targets.

We are encouraged by the Project's understanding of the pressures on NSF's Polar Programs Antarctic Infrastructure and Logistics (AIL) section in supporting a wide range of sophisticated research projects with limited physical and financial resources. It is common, and arguably necessary, for research projects to be very demanding of NSF for field support under the "squeaky wheel" premise. Striving and showing full attention to limited resource utilization is, in our opinion, a productive means of improving project support priority by Polar Programs. We see evidence of such attention in the analysis of fuel needs. It appears similar scrubbing

may have been performed on on-site personnel needs at South Pole, but the back-up documentation for the numbers proposed was not as robust as it was for fuel.

While an unfortunate reality, we are nonetheless pleased that the Project recognizes that uncertainty of funding and approval for consecutive field seasons by NSF represents a major risk to the Project.

A potential risk reduction strategy for consideration by the Project is to further develop its earlier conceived plan for drilling two holes and installing the associated sensors in the second season of field deployment and five in the following year. While this planning may entail a non-trivial effort, we believe such an alternative schedule would reduce risk to the Project's goal and provide a degree of flexibility that AIL may find attractive.

The Project includes several member organizations, including international groups, that have significant roles. As an "academic" based collaboration, there are likely opportunities for some member organizations to quit the partnership when setbacks like year's long delays occur. We are pleased to understand that the Project has kept close communication with its partners to keep them engaged and to get a sense if there is a risk to success because of a defection.

Concerns

Many specific concerns that we voiced during the meeting and amongst ourselves centered around the apparent lack of a fully integrated master schedule. While the Project is not huge in a construction sense, the criticality and limited nature of logistics required are not only uncharacteristic of most non-Antarctic projects but are a very real source for single-point failure manifestation. The Project has demonstrated an understanding of the importance of linkages between, for example, cargo movements from myriad sources to consolidation points with the USAP cargo delivery mechanisms and schedules. However, it appears that no single tool (software) exists to tie all the logistics activities (e.g., cargo and personnel movements) together to allow early recognition of conflicts. We feel such a tool is vital not only in the planning phase, but as Project execution begins. Once field personnel start mobilizing southward, any unexpected disruptions will require an immediate understanding of the "ripple effect" and swift creation of mitigation measures. This task, especially if some of the Project's planners are to be deployed, will be very challenging and prone to error without an integrated master schedule that includes both the preparation and field execution phases. At a minimum we believe an integrated master schedule that is centrally hosted and accessible by all project personnel must exist for all WBS Level 2 and above activities.

Further, during our meeting with the Project, we were not able to view a true Gantt chart. We understood that the scheduling tools being used were unable to produce such a chart, which would clearly show linkages and dependencies between activities, allow mapping of the critical path and near-critical pathways, and a visualization of the float available for each task. We believe being able to see the entire Project schedule and major tasks in a Gantt chart format is vitally important both now during the planning phase and when Project field execution commences. Near the completion of our report preparation, we did obtain a chart showing the critical path; however, there are activities identified as being on the critical path that have no logical links to other activities (e.g., WBS items 1.2.8.5.6.6, 1.2.8.5.7.2.1, 1.2.8.5.7.7.1, 1.2.8.6.14.1, 1.3.1.9.1.2, and 1.3.1.9.2.2).

A dedicated systems engineer function appears to be relatively recent addition to the Project team. We believe this is an indispensable role in a project with this level of complexity and time constraints.

We remain unclear if the Project has created a consolidated list, with quantities and schedules, of the support it will need from USAP resources. Definition of quantities should be in terms like size/geometry/location of snow trenches required, to and from locations and volume of snow to be moved by bulldozer, to and from locations and weight to be towed, fuel amounts and timing, not number of hours or bodies. The latter is NSF's and their contractor's responsibility to determine.

We were not able to assess whether materials being produced or procured for the Project can enter the USAP logistics chain to be in Antarctica a full season in advance of the start of drilling. Given the pandemic-forced delay to field deployment this seems possible. If secure storage can be guaranteed by NSF, pre-season delivery of essential items to Antarctica strikes us as a significant risk reduction strategy.

The topic of "re-baselining" arose on several occasions. While not fully certain of what this exercise will entail, we believe it is important that at least one senior representative from each of the collaborative partner groups of the Project fully participate in the re-baseline activity. This is important for coordination of expectations, in particular cargo deliveries that play a very sensitive role in Project success.

While we understand and embrace the concept of "safety is everyone's job" the nature of the drilling tasks being performed in an environment like South Pole, with serious time constraints, represent a higher than typical set of safety concerns. Having a clearly defined safety lead at each location where and when drilling is taking place (at a minimum) is necessary. And, while population pressure likely precludes having an individual or two whose sole job is safety monitoring, it will be very important that whoever is the safety lead has a primary job assignment that allows them ample ability to always maintain situational awareness. Further, it may be helpful if the on-duty safety lead(s) are easily identifiable by all Project and Station personnel (e.g., neon vest over work coat, and/or uniquely colored hard hat), since nearly all persons outdoors in cold weather gear look very similar.

We complimented the Project on its development of fuel needs estimates. Staffing needs in the field don't appear to be as robustly developed. The Project presented materials illustrating its approach to determining field personnel needs and it was clear that it is challenging to balance work demands on each team member with the aim of limiting the overall berthing allocation needed for the Project. We understand this is a difficult limit to determine.

While the population planning (as presented in the Population Planning PowerPoint) does include the personnel required for sensor installation, we note that the task-labor hours associated with the sensor installation work does not show up on the WBS task-labor hour schedules. Our concern is that while the staffing approach is based on the original IceCube project approach and lessons learned, there is no detailed, linked, comprehensive task-labor hour estimate that substantiates it.

It is unclear if the Project's Cargo Matrix spreadsheet represents a global comprehensive cargo list. As we understand it, the list is based on (a) the original IceCube project approach and lessons learned, (b) customized PID and the SES and TOS checkouts, (c) assessments, repair and retrofit scope, and with the participation of experienced personnel. However, there is no defined process or document that links with the cargo list the PID and associated SES and TOS checkouts, assessments, etc. nor the overall drilling, sensor and cable installation process. Furthermore, it is unclear to what extent this list captures consumables and spare parts, other than with a placeholder line item. We consider that a risk which can be greatly reduced with an effort to rigorously link the PID, the SES and TOS work scoping, the drilling WBS and the overall sensor and cable installation WBS to the cargo list.

Further on the topic of cargo, we did not detect an independent, Project-wide, quality-control/quality-assurance (QA/QC) process to check compliance with packing requirements (for cargo safety/security during transit and meeting USAP cargo regulations) and that all intended items are shipped, from each location, to their intended location, within the planned schedule. It is clear there are experienced cargo logistics experts and cargo SME at each POD site and validation steps to affirm the Cargo Master Matrix spreadsheet is properly maintained; however, we believe that an independent QA/QC component would help minimize overall risk.

We found the Project's presentation "normalizing" and comparing a representative IceCube drilling field season with the planned single drilling season associated with IC/U to be very eye-opening. That several approaches were used to arrive at the comparison lent credibility to the result of that analysis, despite it being done quickly in response to some of our questions and comments. We understood that the analysis concluded that the Project's planned efforts ideally would take about seven days less than the reference IceCube drilling season. This struck us as a very slim buffer. This is even more concerning to us after learning that the planned seven detector holes are considered by the Project to be the minimum definition of success. After seeing the comparison results, our interest in the potential for a split drilling season plan (two in one year and five the following year) greatly increased.

Charge Questions Answered

Cargo Needs:

1) Cargo planning methodology

   a) Are the ground rules and assumptions in IC/U's cargo planning methodology clearly stated in the cargo estimating plan?

      I) YES – RULES AND ASSUMPTIONS CLEARLY STATED IN CARGO ESTIMATING AND SHIPPING PLANNING DOCUMENT.

      II) CONFLICTS IN EXAMPLE USED IN THE CARGO ESTIMATING AND SHIPPING PLANNING DOCUMENT SHOULD BE CLARIFIED/CORRECTED TO AVOID CONFUSION.

   b) Does the cargo planning methodology adequately address special handling requirements or constraints that will drive a specific transportation method?

i) YES, THE CARGO ESTIMATING AND SHIPPING PLANNING DOCUMENT ADDRESSES SPECIAL HANDLING REQUIREMENTS AND CONSTRAINTS THAT WILL DRIVE A SPECIFIC TRANSPORTATION METHOD.

ii) SEE P. 19, SCHEDULE. THE ROS DATE IS REQUIRED TO SHOW THE EQUIVALENT JULIAN DATE. THE THIRD BULLET HAS AN APPARENT TYPO IN THE EXAMPLE "ROS NPX 3152". THERE ARE APPARENTLY DIFFERENT WAYS TO EXPRESS JULIAN DATES. SUGGEST PROVIDING A LINK TO AN APP THAT SHOWS THE DESIRED JULIAN DATE CALCULATOR.

2) Specific Cargo needs:

a) Are the needs for individual cargo items appropriately substantiated? Are the items well documented, i.e., adequately described for use by logistical transport planners? Is the proposed cargo prioritization well substantiated?

I) NEEDS RELATIVE TO WHAT IS REQUIRED FOR SUCCESSFUL SHIPMENT IS WELL DEFINED IN THE CARGO ESTIMATING AND SHIPPING PLANNING DOCUMENT.

II) ITEMS ARE WELL DOCUMENTED IN THE ICU LOGISTICS MATRIX SPREADSHEET FOR USE BY LOGISTICS PLANNERS.

III) CARGO PRIORITIZATION IS BASED ON ROS DATE. THE ROS IS BASED ON THE FIELD SEASON ACTIVITIES AND SCHEDULE, WHICH IS LOGICAL.

IV) PRIORITIZATION BASED ON ROS TENDS TOWARDS A "JUST IN TIME" LOGISTICS STRATEGY. IS THIS BEST APPROACH?

v) THE NEEDS ARE APPARENTLY TAKEN FROM THE ORIGINAL ICE CUBE PROJECT, WITH WELL KNOWN COMPONENTS THAT WERE AND WILL BE REQUIRED FOR THE IC/U PROJECT. THE QUESTION OF HOW THE SPARE PARTS ARE DETERMINED REMAINS TO BE ANSWERED. WAS IT BASED TOTALLY ON FAILURE INCIDENTS IN PRIOR PROJECT? ANY NEW TYPES OF FAILURES FORECASTED?

b) Has UW taken appropriate steps to verify the completeness and cross-check of accuracy of their cargo list?

I) DRILLING WBS ORIGINATED WITH LOCATION, CHECKOUT AND ASSESSMENT OF SES AND TOS EQUIPMENT. THIS RESULTED IN A MODIFICATION, SUBSTITUTION, REPAIR AND REFIT SCOPE AND LOGISTICS REQUIREMENTS, WHICH FORMED BASIS FOR CARGO LIST. IMPLEMENTATION MANAGER LED.

II) THE CARGO LIST IS VERY DETAILED AND APPEARS TO BE COMPLETE AND ACCURATE. THE ADDITION OF A FLOAT COLUMN WOULD HELP HIGHLIGHT TIGHT SCHEDULES AND FLAG NEED FOR EXTRA ATTENTION.

III) THE INSTALL WBS WAS PRIMARILY CENTERED ON DOWNHOLE SENSORS AND SURFACE CABLES. THERE ARE VERY LITTLE ADDITIONAL CARGO REQUIREMENTS ACCORDING TO THE IMPLEMENTATION MANAGER. THE INSTALL IMPLEMENTATION MANAGER LED THIS ACTIVITY.

IV) A CUSTOMIZED PID OF THE SES AND TOS SYSTEM(S) REQUIRED FOR UPGRADE CONFIGURATION WAS DEVELOPED TO ASSESS EQUIPMENT, PARTS, AND SPARES REQUIREMENTS (I.E CARGO) REQUIREMENTS.

V) INSTALL "THOUGHT THRU EACH STEP" THAT WOULD BE REQUIRED ON STATION TO DETERMINE CARGO REQUIREMENTS.

VI) COMPLETENESS AND CROSSCHECK INFORMAL BY HAVING A NUMBER OF EXPERIENCED PERSONNEL REVIEW LISTS.

VII) SUGGEST LINKING LIST OF MATERIALS TO REPAIR/REFIT TASK LIST AND TO ON-ICE STARTUP, TESTING, COMMISSIONING, DRILLING AND SHUTDOWN PROCEDURES. HAVE DEDICATED QC BACKCHECK.

(1) DOCUMENTING REPAIR PARTS LIST, SPARES AND OPERATIONAL REPAIR AND MAINTENANCE SPARES FROM THE PID IS CURRENTLY A WORK IN PROCESS. IT SHOULD BE COMPLETED AND ANY UPDATES TO THE CARGO MATRIX INCORPORATED.
(2) OUT YEAR MATERIALS AND SPARES ARE CAPTURED IN CARGO LIST AS A PLACEHOLDER USING A SET OF SHIPPING MODULES AS THE PLACEHOLDERS. THE SPECIFIC CONTENTS ARE TO BE DETERMINED LATER.

3) Assess the adequacy of risk considerations in the cargo planning methodology:

NOTE THAT THE RISK REGISTER SHOWS "MODERATE" PROBABLILITY IN 100% OF THE 48 HOUR CATEGORY, AND IN ALL BUT TWO OF THE 168 HR PROBABILITY, WITH "LOW" PROBABILITY IN ALL OF THE 336 HR AND 672 HR CATAGORIES.

a) How does the cargo plan incorporate risk mitigation planning (e.g., spare parts)? Are the risk planning methods appropriate or does the panel have suggestions for improvement?

I) A RISK ANALYSIS WAS PERFORMED TO ASSESS THE IMPACT OF DELAYED CARGO ARRIVAL FOR KEY COMPONENTS. HOWEVER, THE ANALYSIS ESTIMATES THE LABOR COST OF THE DELAY TIME ONLY. NO OTHER FORMAL RISK ANALYSIS NOR MITIGATION STRATEGIES DEVELOPMENT WAS ACCOMPLISHED.

II) THE RISK PLANNING PRESENTED IS BASED ON GEN1 LESSONS LEARNED. BUT THERE IS NO FORMAL DOCUMENTATION CAPTURING WHO PERFORMED THE RISK ANALYSIS, WHAT MITIGATION MEASURES WERE ADOPTED, HOW THE ANALYSIS AND RESULTS ARE DOCUMENTED, WHAT QC PROCESS WAS INCLUDED, OR HOW IT TRANSLATES INTO CARGO PLANNING.

III) SOME STATED STRATEGIES THAT RELATE TO CARGO AND POPULATION:

(1) ALL COMPONENTS WILL BE CHECKED PRIOR TO SHIPPING (TO THE EXTENT POSSIBLE).
(2) SPARES WILL BE STOCKED PER GEN1 EXPERIENCE.
(3) LABOR ESTIMATES INCLUDE TIME FOR COMPONENT CHECKING, "MITIGATION MEASURES" AND REPLACEMENTS WITH SPARES. THIS IS BASICALLY BY DEFAULT BASED ON DRILL TEAM MAKEUP AND THEIR TYPICAL WORK SCHEDULE.

IV) OTHER CARGO RISK CONSIDERATIONS NOTED:

(1) FLOAT TIME CONSIDERED IN RDD.

V) CARGO AND POPULATION RISK ASSESSMENT IS SUBSET OF PROJECT RISK AND IS YET TO BE DONE.

(1) COMMENT MADE THAT "UNLIKELY RISK ANALYSIS WILL AFFECT CARGO LIST."

VI) IT APPEARS THAT ALL OF THE HOSE IS SHIPPED FROM ITALY NEW, WHICH WAS A POTENTIAL CONCERN IF USED HOSE HAD BEEN PLANNED. ITEMS WITH ELECTRONICS THAT HAVE BEEN STORED SINCE COMPLETION OF THE ORIGINAL ICE CUBE PROJECT MAY HAVE BEEN EXPOSED TO DEEP FREEZE OR ROUGH HANDLING CAUSING CONCERN FOR RELIABILITY. THESE ITEMS HAVE BEEN OR WILL BE TESTED BEFORE ASSUMING THEY ARE OK. FOR THE D-EGGS BEING SOLE SOURCED AND ALL SHIPPED FROM JAPAN, RECOMMEND SPLITTING THE

TWO CONEX SHIPMENTS ON DIFFERENT CARRIERS TO REDUCE RISK OF LOSS OR DAMAGE DURING SHIPMENT DUE TO SOME CATASTROPHIC ACCIDENT. ALSO, RECOMMEND SHIPPING AN ACCELEROMETER IN ONE OR TWO INITIAL SHIPMENTS TO MONITOR IF THE CARGO WAS SUBJECTED TO ROUGH HANDLING. FOR DNF ITEMS, SUGGEST RECORDING THERMOMETERS TO ASSURE ITEMS WERE NOT SUBJECTED TO EXTREME OUT OF SPEC TEMPERATURES.

VII) RECOMMEND THE FORMAL CARGO RISK ANALYSIS BE COMPLETED, THE PROCESS AND RESULTS DOCUMENTED AND SELECTED MITIGATION STRATEGIES INCORPORATED INTO THE PLANNING.

b) Does the methodology appropriately consider and reasonably quantify the variables and unknowns that enable "what if" analyses to be performed?

I) CARGO DELAY RISK SENSITIVITY ANALYSIS ALLOWS A FORM OF "WHAT IF" ANALYSIS.

II) P. 9 OF THE CARGO ESTIMATION AND SHIPMENT PLANNING *DOES* CONSIDER THE NEED FOR EMERGENT ITEMS AND RESUPPLIES THAT NEED TO BE EXPEDITED, AND PROPER AIR FORCE PALLET USE FOR AIRLIFT. WHILE NO WHAT-IF ANALYSIS WAS DEFINED, THE USE OF EXPERIENCED PERSONNEL IMPLIES THIS WOULD BE DONE WHERE APPROPRIATE.

c) Is the UW assessment of the fuel requirement for drilling deep ice holes well substantiated, with an appropriate level of margin to mitigate risk?

I) YES – BASED ON DETAILED THERMAL MODELING AND GEN1 EXPERIENCE AND LESSONS LEARNED. INCORPORATES SAFETY FACTORS (MID EFFICIENCY SELECTED AND FUEL TO ACCOMMODATE SEVERAL FIRN HOLE RESTARTS). INCORPORATES REAL TIME MONITORING AND TRENDING, ENABLING ADJUSTMENTS IF REQUIRED. WELL DOCUMENTED.

II) THE ASSESSMENT USED A VERY DETAILED ALGORTHMN TO COMPUTE FUEL CONSUMPTION BASED ON A NUMBER OF VARIABLES, WITH A 20% CONTINGENCY FACTOR, AND IS THEN COMPARED TO HISTORICAL FUEL CONSUMPTION FOR A SANITY CHECK. IT APPEARS TO BE WELL THOUGHT OUT. SEE WHITE PAPER ON MODELING HOLE SIZE, LIFETIME AND FUEL CONSUMPTION IN HOT WATER ICE DRILLING. ADDITIONAL FUEL, IF NEEDED, SHOULD BE AVAILABLE FROM THE STATION STORAGE CAPACITY, WITHIN REASON. IT IS ACKNOWLEDGED HOWEVER THAT THERE ARE FEWER AVAILABLE LC-130 FLIGHTS THAT COULD BRING EXTRA FUEL TO THE POLE.

4) Overall, is the IC/Upgrade's cargo method for estimating its cargo needs a reasonable approach? Does it utilize methods that have been successfully used for other projects in the Antarctic? Does the panel have any concerns about the estimating methods used?

I) IT BASICALLY USES THE GEN1 EQUIPMENT AND PROCEDURES. IT IS SCALED AND CUSTOMIZED BASED ON GEN1 EXPERIENCE AND LESSONS LEARNED. TO THAT EXTENT, IT IS BASED ON A PREVIOUSLY SUCCESSFUL APPROACH.

II) DRILLING WBS ORIGINATED WITH LOCATION, CHECKOUT AND ASSESSMENT OF SES AND TOS EQUIPMENT. THIS RESULTED IN A MODIFICATION, SUBSTITUTION, REPAIR AND REFIT SCOPE AND LOGISTICS REQUIREMENTS, WHICH FORMED BASIS FOR CARGO LIST. IMPLEMENTATION MANAGER LED.

III) INSTALL WBS WAS PRIMARILY CENTERED ON DOWNHOLE SENSORS AND SURFACE CABLES. THERE ARE VERY LITTLE ADDITIONAL CARGO REQUIREMENTS ACCORDING TO THE INSTALL IMPLEMENTATION MANAGER. THIS ACTIVITY WAS INSTALL IMPLEMENTATION MANAGER LED.

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VIII) SUGGEST IDENTIFYING DEDICATED QC PERSON FOR EACH CARGO POD. THEY WOULD USE CHECKLIST GENERATED FROM CARGO ESTIMATING AND SHIPPING PLANNING DOCUMENT TO CHECK CARGO AFTER PACKING BEFORE SHIPPING. THIS COULD BE FURTHER BACKCHECKED BY VALIDATOR(S).

IX) THE MAJORITY OF THE PERSONNEL ON THE IC/U PROJECT PERSONNEL ARE EXPERIENCED FROM THE ORIGINAL ICE CUBE PROJECT, SO THEIR EXPERIENCE IS VERY VALUABLE TO THE IC/U EFFORT AND SHOULD RESULT IN A REASONABLE APPROACH. SUPPLY CHAIN PROBLEMS EXPERIENCED ON THE WEST COAST ARE LIKELY TO PERSIST BUT THERE SHOULD BE ADEQUATE FLOAT WITHOUT PADDING THE ROS DATES. THEY ARE RELIANT ON AIL TO WORK THOSE ISSUES SINCE UW DOES NOT HAVE CONTROL OVER THESE ISSUES.

On-Ice Labor (Individual People and FTEs) Needs:

1) Effort planning methodology:

a) Are the ground rules and assumptions for people and labor effort in each location (McMurdo, South Pole) in Antarctica clearly stated in the estimating plan? Examine the methodology used to extrapolate labor estimates from original IceCube construction experience to the IC/U and advise on their appropriateness. Was the planning done by individuals with the appropriate skills and expertise?

I) ASSUMPTIONS CLEARLY DEFINED IN POPULATION PLANNING PAPER.

II) LABOR ESTIMATES BASED ON TASK-LABORHOUR ANALYSIS.

III) THE FIELD SEASON TASKS AND STAFFING OUTLINED IN THE POPULATION PP SEEM LOGICAL AND SHOW SIMILARITY TO THAT DESCRIBED IN THE ICECUBE EHWD FUNCTIONAL DESCRIPTION PAPER.

IV) POPULATION PLANNING LED BY IMPLEMENTATION MANAGERS.

V) THE METHODOLOGY SEEMS REASONABLE BUT THE LEVEL OF DETAIL IN THE TASK-LABOR HOUR ANALYSIS HAS RAISED CONCERNS.

VI) ASSUMPTIONS WERE DISCUSSED IN THE POPULATION PLANNING DOCUMENT, PRODUCED BY KEY PEOPLE FROM THE ORIGINAL PROJECT. GROUND RULES, SUCH AS AVOIDING PEAK TRAVEL LOADING AND EXPECTATONS ARE DISCUSSED IN THE PLANNING DOCUMENT.

b) Do the labor estimates identify types of labor needed using the same categorization as the IceCube Cost Estimating Plan?

i) YES. FOR EXAMPLE, SPECIFIC SKILLSETS ARE LISTED IN THE DRILL CREW MAKEUP DOCUMENT WITHIN THE POPULATION PAPER.

2) Specific effort needs:

a) Are the on-ice labor estimates appropriately substantiated and traceable to budget estimates?

I) UNCLEAR ABOUT "TRACEABLE TO BUDGET ESTIMATES."

II) LABOR ESTIMATES BASED ON TASK-MANHOUR ANALYSIS.

III) FIELD SEASON TASKS AND STAFFING OUTLINED IN THE POPULATION PP SEEM LOGICAL AND SHOW SIMILARITY TO THAT DESCRIBED IN THE ICECUBE EHWD FUNCTIONAL DESCRIPTION PAPER.

b) Do the people requirements and the multi-year effort profile appear to be complete and accurate?

I) YES - FIELD SEASON TASKS AND STAFFING OUTLINED IN THE POPULATION PP SEEM LOGICAL AND SHOW SIMILARITY TO THAT DESCRIBED IN THE ICECUBE EHWD FUNCTIONAL DESCRIPTION PAPER.

3) Risk considerations in the effort planning methodology:

a) How does IceCube's labor estimate incorporate risk planning considerations? Are the risk planning methods appropriate or does the panel have suggestions for improvement?

I) TO A LIMITED AMOUNT, SUCH AS A MEMBER OF THE CREW BEING SICK FOR A DAY OR TWO. THERE ARE ALTERNATES SHOWN FOR SEASON TWO, BUT NOT FOR SEASON 3.

II) A RISK ANALYSIS WAS PERFORMED TO ASSESS THE LABOR COST IMPACT OF DELAYED CARGO ARRIVAL FOR KEY COMPONENTS. HOWEVER, IT IS UNCLEAR HOW THIS MIGHT HAVE IMPACTED PLANNING.

III) POPULATION RISK ANALYSIS IS A SUBSET OF THE PROJECT RISK ANALYSIS BUT IS NOT COMPLETE OR UPDATED.

IV) TASK-LABOR ESTIMATES BASED ON GEN1 LESSONS LEARNED.

V) LOOSE RISK PLANNING IS BASED ON GEN1 LESSONS LEARNED. BUT THERE IS NO FORMAL DOCUMENTATION CAPTURING WHO PERFORMED THE RISK ANALYSIS, WHAT MITIGATION MEASURES WERE ADOPTED, HOW THE ANALYSIS AND RESULTS ARE DOCUMENTED, WHAT QC PROCESS WAS INCLUDED, OR HOW IT TRANSLATES INTO POPULATION PLANNING.

VI) SOME STATED STRATEGIES THAT RELATE TO POPULATION:

(1) LABOR ESTIMATES INCLUDE TIME FOR COMPONENT CHECKING, "MITIGATION MEASURES" AND REPLACEMENTS WITH SPARES. THIS IS BASICALLY BY DEFAULT BASED ON DRILL TEAM MAKEUP AND THEIR TYPICAL WORK SCHEDULE.

VII) OTHER LABOR RISK CONSIDERATIONS NOTED:

(1) DRILL STAFFING ACCOMMODATES A SICK CREW MEMBER.

(2) DRILL SCHEDULE ACCOMMODATES ABANDONING AND RESTARTING A NUMBER OF FIRN HOLES.

(3) EXECUTION PLAN INCLUDES RETAINING BACKUP FIELD PERSONNEL.

VIII) RECOMMEND THE FORMAL POPULATION RISK ANALYSIS BE COMPLETED, THE PROCESS AND RESULTS DOCUMENTED AND SELECTED MITIGATION STRATEGIES INCORPORATED INTO THE PLANNING.

b) Does the labor estimation methodology consider and reasonably quantify known risk factors other variables that enable "what if" analyses to be performed?

I) TO THE EXTENT REASONABLE.

c) Advise NSF on the soundness of plan for prioritizing among labor categories if NSF must revise its capabilities to support IC/U needs.

i) THE PLAN TO RESPOND TO A REVISION OF NSF ABILITY TO SUPPORT NEEDS IF THEY MUST BE REDUCED WAS NOT DEFINED, BUT THAT BRIDGE WOULD HAVE TO BE CROSSED BASED ON THE EXTENT OF THE NEEDED PERSONNEL REDUCTIONS. CROSS TRAINING WILL HELP PROVIDE FLEXIBILITY IN THIS MATTER.

4) Overall, are the effort/people estimating plan (the methodology used to estimate the number of field team members, the labor categories, and the number and types of direct support contractors) a reasonable approach? Have the used planning methods been successfully applied to other projects in the Antarctic?

I) IT IS BASICALLY MODELED AFTER THE GEN1 PLAN. IT IS SCALED AND CUSTOMIZED BASED ON GEN1 EXPERIENCE AND LESSONS LEARNED. THE FIELD SEASON TASKS AND STAFFING OUTLINED IN THE POPULATION PP SEEM LOGICAL AND SHOW SIMILARITY TO THAT DESCRIBED IN THE ICECUBE EHWD FUNCTIONAL DESCRIPTION PAPER.

II) FS1 ACTIVITIES FLOW FROM SES & TOS CHECKOUTS, ASSESSMENTS, REPAIR AND RETROFIT TASKS.

III) FS3 STAFFING, ACTIVITIES AND TIMELINE BASED ON DRILLING WORK SEQUENCE AND DETAILED DRILLING MODELING.

IV) INSTALLATION LABOR HOURS ASSOCIATED WITH CABLING AND SESNOR INSTALLATIONS NOT YET DEVELOPED (RESPONSE TO DETAILED QUESTION #3A).

V) OVERALL METHODOLOGY PRESUMED TO BE SAME METHOD AS GEN1, ADJUSTED FOR NEW MORE LIMITED FLIGHT RESTRICTIONS, WHICH MAKE THIS PROJECT MORE DIFFICULT.

VI) THE EFFORT AND STAFFING ESTIMATING PLAN FOR THE DRILLING RELATED ACTIVITIES ARE BASED ON A REASONABLE APPROACH AND ARE SIMILAR TO THAT SUCCESSFULLY USED PREVIOUSLY, GEN1. IT IS UNCLEAR THE LEVEL OF DETAILED TASK-LABOR HOUR ESTIMATING THAT HAS BEEN DONE USING DISCRETE RESOURCES. ALSO, THERE HAS BEEN TO DATE NO DETAILED INSTALLATION RELATED TASK-LABOR HOUR ESTIMATING DONE.

Combined Considerations in Planning Cargo and People Needs:

1) Advise NSF on the validity of the logic linking IC/U's requested cargo transport delivery sequence with IC/U's proposed schedule profile of people and effort needed in Antarctica (McMurdo and South Pole).

   A) THE LOGIC SEEMS VALID. THE CARGO AND POPULATION PLANNING FLOW FROM A PROJECT WBS. THE WBS IS A SCALED AND CUSTOMIZED VERSION OF GEN1 AND INCORPORATES THE EXPERIENCE AND LESSONS LEARNED FROM GEN1. THE CARGO DELIVERY SEQUENCE IS BASED ON THE ROS WHICH FLOWS FROM THE WBS.

   B) IT APPEARS THAT THE ROS DATES ARE REASONABLE, AND TOTALLY RELIANT ON AIL PERFORMING AS NEEDED TO MEET THOSE UNPADDED REQUIREMENTS. CRITICAL ITEMS HAVE BEEN SHOWN TO BE PACKAGED ON AF PALLETS SO THEY COULD BE MOVED TO AIR SHIPMENT IF NEEDED, TO ASSIST IN PROVIDING FLEXIBILITY TO AIL IN THE EVENT OF PROBLEMS.

2) Has IceCube appropriately considered and reasonably quantified the probabilities and impacts of the most important risk scenarios in its risk planning? Consider likely risk scenarios that could cause shortfalls in logistical capabilities (weather delays, shipping delays, extra material needs, aircraft availability, limited availability of key staff, etc.).

   I) RISK PLANNING FOR CARGO AND POPULATION A SUBSET OF PROJECT RISK ANALYSIS BUT HAS NOT BEEN ACCOMPLISHED/UPDATED.

   II) PROBABILITIES OF LIKELY RISK SCENARIOS NOT INCLUDED.

   III) THE PROBABILITY OF CARGO DELAY FOR KEY ELEMENTS AND THE IMPACT OF THAT SCENARIO ON LABOR COSTS IS PROVIDED.

   IV) THE FACTORS HAVE BEEN IDENTIFIED (I.E., AIRCRAFT AVAILABILITY, SHIPPING DELAYS, ETC.).

   V) INFORMAL RISK CONSIDERATIONS HAVE BEEN TAKEN INTO ACCOUNT ACCORDING TO DISCUSSION. AND STRATEGIES HAVE BEEN SUGGESTED TO MITIGATE CERTAIN RISKS (I.E., SPARE PARTS, TESTING BEFORE SHIPPING, TIME SET ASIDE FOR REPAIRS, FLOAT IN RDD, ETC.).

   VI) SINCE IC/U HAS NO CONTROL OVER DELAYS, THEY CAN ONLY PROVIDE UNPADDED ROS DATES AND RELY ON AIL TO PERFORM. PLANS TO WORK AROUND RISKS BEYOND THAT NEED TO BE EXECUTED BASED ON THE FACTS AT THE TIME.

   a) Has the IC/U team appropriately utilized the sensitivity analysis methods incorporated in the cargo and people planning to credibly forecast the contributions of the cargo and effort budgets to a Total Project Cost (TPC) with a 90% confidence level budget and schedule, given the forecast impacts of known risks. (Note, the TPC estimate will be assessed at the re-baseline review planned for Feb-March 2022).

      I) IT WOULD APPEAR THAT THE SENSITIVITY ANALYSIS IS BASED ON THE EXPERIENCE OF THE TEAM, AND THE TEAM IS VERY EXPERIENCED.

   b) Is the sensitivity analysis traceable?

      I) UNABLE TO DETERMINE.

      II) THE LACK OF A SINGLE INTEGRATED MASTER SCHEDULE AND COMPREHENSIVE RISK REGISTER MAKES IT DIFFICULE TO PERFORM A SENSITIVITY ANALYSIS TO A DEFINED CONFIDENCE LEVEL.

RECOMMENDATIONS/SUGGESTIONS

- Project team should perform their own schedule analysis using the 10 Best Practices for a high-quality and reliable schedule discussed in the GAO Schedule Assessment Guide (GAO-16-89G) for guidance and deliver their self-assessment to NSF at their next project review.
- Produce graphic that shows all planning tools being used and how they feed and/or link with each other. Additionally, identify who is the single point of contact and/or manager for each planning tool and its roll-up destination.
- Consider mechanization of cable pulling operations up the ICL towers to reduce labor and potential for injury.
- Research potential advantages of heating the cables in the area where they enter the ICL towers to make snaking them from the snow trench into ICL easier.
- Give serious consideration to splitting shipments of the two Conex vans of D-eggs into two carriers to reduce potential impacts of an accident with one.
- Extend tolerance or recommended alternate location for GPR scan of proposed nine firn holes and cable trenches to CRREL and define the level of fidelity needed.
- Planning should identity the schedule float that exists between the earliest and latest dates when deliverables must be ready to enter the USAP logistics system. Add a float column with conditional formatting (red, yellow, green; based on number of days) in the cargo spreadsheet.
- Include recording accelerometer in sample packaging for first available South Pole Traverse to get a sense of the potential for shock and vibration damage during shipment using the traverse.
- Activities planned for the same construction season should be prioritized before the start of the season to ensure resources are applied to the most critical activities should delays begin to be experienced.
- Drilling activities in the schedule should be broken down into smaller duration activities to allow for better visibility of the entire drilling process and to allow planned efficiency when staff are expected to move from one hole to the next.
- Drilling activities should include some buffer time to allow for inefficiencies experienced at shift changes and mid-day breaks.
- The Excel spreadsheet that was provided as an output from Smartsheet showed that generic resources are applied for tasks occurring in the same time period. EN and TE are the two most common resource types. With multiple activities occurring during the same time frame that use EN and TE resources it is not possible to determine if the planned staffing is over or under allocated. This can be solved by creating unique resource names (SHFT1_ENG, SHFT1_DRL, SHFT1_HOS, SHFT2_ENG, SHFT2_DRL, etc.). This may provide for a better analysis of the resource loading and population planning.
- The risk register should include both technical risks and programmatic risks. An analysis of the risk register should include looking for pairs of risks that are correlated (i.e., if Risk A happens, then the probability of Risk B increases).

CONCLUSIONS

The IceCube Upgrade planning team are an impressive group with extensive experience uniquely appropriate for the Project's goals. They demonstrate excellent teamwork and dedication to the task at hand.

We view the Project's reliance on personnel and equipment from the successful construction of the original IceCube array and the follow-on DeepCore project as not only wise, but vital to the success of IC/U.

The approach and tools used to plan the Project are good, but we believe the master schedule would be more robust if all the planning and tracking tools currently in use would be integrated into a single master schedule that is the primary source for all information related to logistics planning and tracking. This would help reduce the potential for information contained in separate planning spreadsheets to become outdated or incorrect.

Being a group of individuals with more than 150 years of polar engineering practice, it was not difficult for us to generate endless questions. We were impressed that the IC/U team seriously considered and eagerly addressed these questions, often on very short notice. So, while we have made many suggestions and recommendations in this report, we are unanimous in our opinion that the IC/U team are on the right track to achieve the planned additional sensor strings to the center of the existing IceCube neutrino telescope at South Pole.