# Class D Management Implementation Approach of the First Orbital Mission of the Earth Venture Series

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### ABSTRACT

A key element of the National Research Council's Earth Science and Applications Decadal Survey called for the creation of the Venture Class line of low-cost research and application missions within NASA (National Aeronautics and Space Administration). One key component of the architecture chosen by NASA within the Earth Venture line is a series of self-contained stand-alone spaceflight science missions called "EV-Mission". The first mission chosen for this competitively selected, cost and schedule capped, Principal Investigator-led opportunity is the CYclone Global Navigation Satellite System (CYGNSS).

As specified in the defining Announcement of Opportunity, the Principal Investigator is held responsible for successfully achieving the science objectives of the selected mission and the management approach that he/she chooses to obtain those results has a significant amount of freedom as long as it meets the intent of key NASA guidance like NPR 7120.5 and 7123. CYGNSS is classified under NPR 7120.5E guidance as a Category 3 (low priority, low cost) mission and carries a Class D risk classification (low priority, high risk) per NPR 8705.4. As defined in the NPR guidance, Class D risk classification allows for a relatively broad range of implementation strategies. The management approach that will be utilized on CYGNSS is a streamlined implementation that starts with a higher risk tolerance posture at NASA and that philosophy flows all the way down to the individual part level.

**Keywords:** Earth Venture, CYGNSS, Class D, NASA

## 1. INTRODUCTION

In response to the recommendations made in the National Research Council's Earth Science and Applications Decadal 2007 Survey, the Earth Science Division (ESD) within National Aeronautics and Space Administration (NASA) has developed the Earth Venture line of missions. The Earth Venture portfolio is based on an optimal mix of suborbital investigations, full orbital missions, and orbital instrument opportunities that are released on a regular basis and implemented through the Earth System Science Pathfinder (ESSP) Program Office at the Langley Research Center (LaRC). The Earth Venture line complements the systematic missions identified in the Decadal Survey, and provides flexibility to accommodate scientific advances and new implementation approaches as well as providing an avenue for lower cost-higher risk missions.

The first orbital mission chosen for this competitively selected, cost and schedule capped, Principal Investigator-led opportunity is the CYclone Global Navigation Satellite System (CYGNSS). The goal of CYGNSS is to understand the coupling between ocean surface properties, moist atmospheric thermodynamics, radiation, and convective dynamics in the inner core of a tropical cyclone. The CYGNSS mission is comprised of eight Low Earth Observing (LEO) microsatellites that use GPS bi-static scatterometry to measure ocean surface winds. The PI is housed at the University of Michigan (UM) and has teamed up with the Southwest Research Institute (SwRI) for project management and implementation. CYGNSS was selected in June of 2013 with contract award to UM and subsequently to SwRI in December of 2013. This paper was written in July 2014 just after the CYGNSS Systems Requirements Review (SRR) / Mission Definition Review (MDR) and the Key Decision Point - B, the transition to Phase B.

As specified in the defining Earth Venture -2 Announcement of Opportunity, the Principal Investigator (PI) for CYGNSS is held responsible for successfully achieving the science objectives of the selected mission and the management approach that he chooses to obtain those results has a significant amount of freedom as long as it meets the intent of key NASA guidance like NPR 7120.5 and 7123. CYGNSS is classified under NPR 7120.5E guidance as a Category 3 (low priority, low cost) mission and carries a Class D risk classification (low priority, high risk) per NPR 8705.4. As defined in the guidance, the Class D risk classification allows for a relatively broad range of implementation strategies. However, the cost and schedule capped nature of the Earth Venture program will always constrain the PI to deliver their project on schedule and within budget.

For the Earth Venture line of mission, NASA consciously selected the Category 3 and Class D designations to open up the management options for these systems. This decision was not made due to low interest in the scientific merit of the technologies being employed, but to open up the management options available to the PI since it has been recognized that the standard management processes used on "typical" spaceflight missions can be somewhat overwhelming (and cost prohibitive) for the small "higher risk-higher reward" missions targeted for the Earth Venture line of orbital missions. The modification to standard management practices that will be used on CYGNSS is a streamlined implementation that starts with a potentially higher risk tolerance posture at NASA and that philosophy flows all the way down to the individual piece part level. Employment of this approach is expected to focus more on proper requirements, efficient communications and PI flexibility that is balanced with appropriately leveled risks rather than relying on "normal spaceflight processes" to manage the project.

## 2. EARTH VENTURE PROGRAM IMPLEMENTATION FOR CYGNSS

NASA has the responsibility for Program administration for all Earth Venture missions. For Class D missions, this role is accomplished with moderate insight and limited oversight, thus necessitating a streamlined reporting and review process. Even though meeting the intent of guiding NASA principles and guidelines for good spaceflight project management is expected, tailoring of these features is also expected when implementing a Class D philosophy. The codification of the mission management and implementation approach is captured in key guiding project documents.

Program authority starts at Science Mission Directorate Associate Administrator (AA). As captured in Figure 1, this authority flows through the Earth Science Directorate Division Director and Flight Director down to the ESSP Program Manager and ultimately is implemented at the CYGNSS Project level. The ESSP Program Office is charged with day-to-day oversight and insight responsibility.

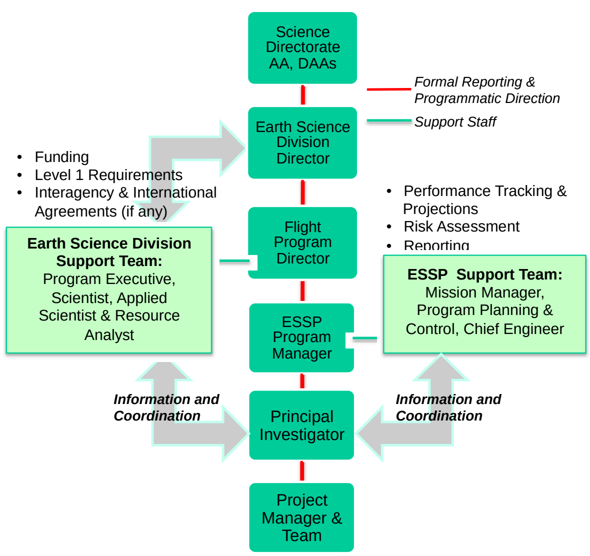


Figure 1. Earth Venture Communication and Authority Chain

Since CYGNSS is not housed at a NASA Center, the “host center” responsibilities default to the Langley Research Center, the center at which the ESSP Program Office is housed. As host center, LaRC is responsible for providing the Engineering Technical Authority and Safety and Mission Assurance Technical Authority functions as well as ensuring compliance with the intent of the technical authority requirements captured in 7120.5.

The guidance listed in the EV2 Announcement of Opportunity is that all proposers that responded to the solicitation should provide an implementation structure that meets the intent of key guiding NASA policy like NPR 7120. 5 (NASA Space Flight Program and Project Management Requirements) and NPR 7123.1 (NASA Systems Engineering Processes and Requirements) but that they were not required to be bound to these NPRs if they had management policies in place that met the intent of these guiding principles. As part of the management approach chosen by the PI for CYGNSS, a decision was made to adhere to the foundation philosophies of 7120.5 and 7123.1. This early decision paved the way for NASA to communicate openly with the Project team on a common set of measuring sticks for which NASA and the Project team could assess performance.

Key underlying tenants of the CYGNSS management approach were to be captured in high-level documents like the Formulation Agreement and the Project Plan. The Formulation Agreement is used to capture the technical and programmatic approach that is used during the Formulation Phase (aka Phase A and Phase B) of project development as well as a place to codify schedule and funding requirements. Since this document is signed by key personnel within NASA and the CYGNSS Project, it also serves as a tool to communicate programmatic plans as well as capture agreements to the tailoring of 7120.5. Likewise, the Project Plan serves the same role as the Formulation Agreement except that it defines the technical and programmatic approach for the Implementation Phase (aka Phase C through Phase F) of the project life cycle. Both of these documents are also used to capture the tailoring agreements between NASA and the PI for the Formulation and Implementation life cycle phases.

Another tenant of the Class D approach involves the project’s ability to define the goodness of each deliverable. This refers to every deliverable, from initial contracts and work agreements to formal documents such as Project Plans and System Engineering Management Plans. Typically NASA’s requirements define the deliverable as well as figure of merits that the deliverable is measured by. Add to this the experience based expectations for each of those deliverables and the expectation for conformity and quality can be rather stringent. With the Class D management approach used for CYGNSS, NASA is working to accept the project’s deliverables as “good enough”. This entails no less expectation to the meeting of the requirement, but a broad allowance as to the way the requirement is met. Format or adherence to “the way it has always been” is thrown out. A deliverable is assumed good if the intent of the requirement is met. Furthermore, the burden of proof on the goodness of any approach or deliverable is on the Program and not on the Project. If the Program believes that a deliverable is not sufficient, they must expressly define the areas of deficiency rather than the Project bearing the proof as to why a document is “good enough”. This approach is expected to reduce the workload of the Project in polishing deliverables or the workload of conforming to expectations that are above what is required.

To reduce potential workload on the Project team, an effort was made to streamline the reporting process. On a monthly basis, the CYGNSS Project team reports technical and programmatic status to the ESSP Program Office, LaRC Technical Authority, as well as to the HQ Program Executive (PE). The Program Office, Technical Authority representatives, and PE then use this data, as well as insight gained during the informal weekly telecom, to fill monthly reporting requirements to the LaRC Center Management Council, Engineering Project Technical Review, and Flight Program Review respectively without impacting the Project team. Open communication between the Program and the Project, allows the advocacy for the Project at multiple stakeholder levels within and external to NASA without slowing the Project team down

As the CYGNSS Project Team nears the completion of key life cycle milestones, the Project team is expected conduct the typical life cycle reviews (SRR, PDR, CDR, SIR, and ORR) but is provided flexibility in the path to approach these reviews. The Science Mission Directorate at HQ will continue to use Key Decision Points B-F as the decisional gates to verify that the Project team has completed each life cycle phase and is prepared to move to the next phase.

Another area where the CYGNSS-implemented Class D management approach is different from a normal Class B or Class C management approach is demonstrated in the area of independent cost and schedule analysis before a life cycle review. For a Class B/C Project, the Project is typically required to provide an independent cost estimate (ICE) and an independent schedule estimate (ISE) for each life cycle review. It is also possible that the Standing Review Board (SRB) would acquire an additional ICE and ISE of their own and there could even be a third independent assessment chartered by HQs or the Program Office. Presentation of these assessments would include the Projects reconciliation of one or more independent views of the Projects cost and schedule. The approach chosen for the first Class D Earth Venture orbital mission has been to utilize a single ICE/ISE chartered from outside of the Project. This initial assessment is mostly analogy based and utilizes the Project's AO proposal and deliverables up to the first life cycle review. Subsequent ICEs and ISEs will involve the project's performance baseline and matured risks and mitigations. The use of a single ICE/ISE for HQs, the Program Office, and the SRB minimizes data pull from the Project. The bigger pull back for Class D means that the Project is not required to perform reconciliation. The Program Office is responsible for performing a qualitative, integrated assessment of cost, schedule, risk and technical performance with consideration of the ICE/ISE as a major input. This assessment is meant to determine the projects preparedness to move forward to the next life cycle phase.

As defined in the Announcement of Opportunity, NASA expects the PI to implement the mission with risk characteristics that are consistent with those described for a Class D mission as found in NPR 8705.4. NASA is holding the PI accountable to implement a risk management process that has sufficient rigor to support the identification, assessment, and resolution of risks just as is expected for all NASA missions. However, as part of the Class D approach to risk management, NASA is willing to potentially adopt a risk posture on a given risk or series of risks that is higher risk than what might be typically accepted on a more typical Class B or Class C spaceflight mission. For example, in the Earth Venture-2 AO, NASA specifically stated that it is allowable to launch on an uncertified launch vehicle or be the first payload on a new launch vehicle. But the bottom line for the Class D risk approach is that NASA should be well informed of the potential risk, carefully evaluate the potential outcomes of the risk, and then make a conscious decision that the range of potential outcomes is worthy of the risk being accepted. It can really be summed into a bumper sticker style slogan of "risk tolerance, not risk ignorance".

## 3. CYGNSS PROJECT IMPLEMENTATION

One of the first questions that the ESSP Program Office asked the CYGNSS project after selection was "what is the Project's definition of Class D". The only NASA document that even discusses different classes of missions is NPR 8705.4 "Risk Classification for NASA Payloads" and it only addresses the differences in requirements between classes at a very high level. The two prime NASA requirements documents, 7120.5E and 7123, are agnostic to mission class. Likewise NPR 7150.2a, the software requirements document, also does not address different mission classifications. All of these documents are written "one size fits all" for all NASA missions with the understanding that the requirements can be tailored. The premise is that a Class D mission can tailor out or modify requirements to lessen the "procedural process" burden on the project because a Class D mission may potentially accept a higher level of risk.

The CYGNSS project team of UM and SwRI has the advantage that both organizations have worked on NASA missions across the spectrum of acceptable risk. On one end of the spectrum, sounding rockets and CubeSats represent minimal paperwork and analysis, less oversight and reviews, potentially reduced testing and ultimately the associated increased risk. On the other end of the spectrum, UM and SwRI have worked on large DOD and NASA Class B and C missions and thus are very familiar with the requirements and paperwork on missions with a lower level of acceptable risk. Because NASA Class D projects are relatively new, most institutions including UM and SwRI do not have processes, procedures, and documentation written and tailored for a Class D project. Pulling processes from Class B/C missions or from sounding rockets / CubeSats both have inherent issues. Using Class B/C documentation is frequently overkill for a Class D project and it is very easy to accidentally leave in requirements that are not needed. Likewise, sounding rockets and CubeSat processes and procedures typically do not have the rigor needed by a Class D project. In general for CYGNSS, the Project "tailored down" documentation from two recent projects MMS (Class B) and IBEX (Class C) to try to get a management and system engineering plan that made sense for a Class D project. It should also be noted that several existing institutional processes (i.e. document control, controlled stores, non-conformance system, etc.) are being used "as is" with the thought that it would cost more money and time to tailor down these existing products/services rather than to just use the higher maturity systems that the team is familiar with. Lastly, rather than going straight to Class D, the approach that the CYGNSS Project management team has adopted is to plan and work as if it is a Class C project and then to fall back and descope to Class D as needed to stay within the cost and schedule cap. The Principal Investigator and his management team felt that this is the lowest risk method while still meeting the EV-2 AO requirements.

**Specific Project Changes for Class D Implementation**

**Management**: CYGNSS is not only a Class D mission but it is also a Principal Investigator (PI) led mission. On a PI mission, the PI is the ultimate authority. With Class D categorization, this is even more important. The PI has the authority to set the requirements and what is acceptable to descope or not do. At the recommendation of the Standing Review Board (SRB) following the SRR/MDR, one of the key Phase B tasks will be to develop an "incompressible test list" with trigger points that will document tests that can be deleted to save schedule and/or dollars. To delete a standard test on a typical NASA mission usually requires the convening of a Material Review Board, a waiver and ultimately a lot of back and forth between all stakeholders. On a Class D PI-led mission, the deletion of a standard (non-safety critical) test is up to the PI, However, the plan will certainly be reviewed by all stakeholders but the ultimate authority resides with the PI. The SRB (and NASA headquarters at the KDP-B) also suggested the review of other future project activities and deliverables and to only do what makes sense for a Class D mission. To date, the largest area of tailoring has been the combining of reviews, the SRR/MDR is a good example. So far the scope and content of future reviews is per 7120 and 7123. A scrub of all future activities and their scope and content will be reevaluated in Phase B.

There are several other key management strategies employed by CYGNSS that are not really due to being Class D but rather because the project is cost and schedule capped. The Project has deliberately kept the team small to maximize communication. It is far better to have someone dedicated full time to the project than to have two people at only 50%. Likewise, the project organization is very flat and integrated. Each spacecraft subsystem lead reports directly to the mission Project Manager and Mission System Engineer. UM and SwRI project management are in almost constant communication and work as partners rather than the more typical prime-subcontractor paradigm. Lastly, and again to minimize the project team, some traditional subsystems have been combined (i.e. Mechanical with Thermal, Command and Data Handling with Communications).

**Systems Engineering:** CYGNSS systems engineering is largely the same as any Class B/C mission. The only "down tailoring" that is planned is using existing data sheets and/or user manuals as Interface Control Documents (ICD's) for heritage or Commercial Off The Shelf (COTS) components rather than "rewriting" them. The Project does plan on putting the ICD's under configuration management and will include interface requirements in the DOORs database to ensure proper verification.

**Safety and Mission Assurance (S&MA)**: The S&MA arena is the area with the least and most changes associated with being a Class D mission. From a Safety standpoint, 8705.4 treats all NASA missions the same regardless of class thus a Class D mission has all the same requirements as a Class B or C mission. Conversely from a reliability standpoint, 8705.4 relaxes the requirements on reliability analysis to only safety critical items and provides significant leeway on parts quality. With the Class D moniker, the traditional reliability analysis are only required for safety critical aspects of CYGNSS. The Project is planning on developing more than “safety critical analysis” only, as this is “good spaceflight practice” but the additional analysis will not have to have the formality of being a deliverable to NASA. Likewise, the Project is taking advantage of not having to use a full Grade 2 parts program which not only provides significant savings in cost but also allows the use of newer higher performance parts. The Project’s general parts choices start at EEE-INST-002 level 3 and then fall to vendor High Reliability (Hi-Rel), to Automotive Grade, and finally to parts with established reliability with a Mean Time Between Failure (MTBF) of 500,000 hours. The Project will utilize a Project-led Parts Control Board to evaluate and approve all flight parts.

**Software:** As mentioned previously, NPR 7150.2a, the software requirements document, is agnostic about mission class. The Project plans to use CYGNSS as a pathfinder for future Class D missions. SwRI is an experienced CMMI Level 5 organization with existing procedures mapped to NPR 7150.2a and will use this heritage experience to develop tailoring guidelines for Class D missions. A separate paper is also being prepared for the 2013 SPIE conference titled “Software Engineering Processes for Class D Missions” containing details of the proposed plan for Class D software management. In general, that paper suggests the tailoring of NPR 7150a to include such things as the creation of joint software plans and specifications, merging of software and program level activities, and the reduction of the number of formal reviews

**Testing:** CYGNSS is not only unique as a Class D PI-led mission, however it is different in that it is made up of eight microsatellites. Because of this, and the limited freedom of being Class D mission, the mission is afforded greater flexibility in testing options. At one extreme, the Project could test one observatory and say the other 7 are qualified by similarity. However, the CYGNSS team's current testing plans are actually closer to the other extreme. The Project is planning on a ~Class B/C protoflight test program in the integrated master schedule as well as a verification plan for all observatories. The Project will then leverage anything greater than the previously mentioned incompressible test list as a method to descope any additional testing to stay within the cost and schedule cap. The incompressible test list will be captured in the update to the Project Plan.

## 4. SUMMARY

The new NASA line of Earth Venture Missions is expanding the NASA portfolio. It provides the opportunity for "higher risk-higher reward" science opportunities, smaller and more cost efficient spacecraft, and culturally different management processes. The allowable use of Class D management is unfamiliar ground for NASA's Earth Science Division and the playbook is open for potentially new implementation strategies. Since CYGNSS is the first of these missions, the management approach continues to mold to complement the implementation approach used by the PI-led CYGNSS project team. This moving and moldable process will continue to evolve for the NASA Earth Venture Program and the CYGNSS Project team thus allowing the PI flexibility but yet meeting the intent of key tenants of NASA guidance. It will remain a constant challenge for both the Program and Project to maintain the Class D allowable flexibility and refrain from going back to the familiarity of the Class B/C way of doing business. As the Project progresses thru Phase B, the specifics of Class D management approach will continue to unfold.