

# **NASA Earth Science Senior Review 2015**

## **Addendum Report for QuikSCAT Out of Cycle Extension Review**

Submitted by: Guosheng Liu (Chair), Sarah Gille, Linwood Jones, Douglas Vandemark, John Haynes, Neil Weston, Waldo Rodriguez, Stephen Jenne, Cheryl Yuhas

### Background

The Earth Science Division conducted an out-of-cycle mission extension review for QuikSCAT in March 2016.

The Quick Scatterometer mission was included in the 2015 Senior Review, but the mission team declined to propose for extension, based on the successful performance of its follow-on mission, the ISS-RapidScat payload. The mission was therefore not evaluated by the Senior Review panel during its review March-May, 2015. Subsequent to the review, ISS-RapidScat developed technical problems that called into question its ability to replace QuikSCAT as the calibration standard for future Ku-band scatterometers, and the ESD Steering Committee reserved the option to consider extension of QuikSCAT.

In September 2015, ESD deferred QuikSCAT decommissioning to no earlier than Feb 2016, to allow time for further assessment of the RapidScat state of health and for the Ocean Vector Winds Science Team to investigate alternative methods of maintaining the climate data record. At the same time, ESD initiated planning for an out-of-cycle extension review of QuikSCAT. In accordance with the SMD process for Senior Reviews, ESD proposed and received concurrence from the SMD Science Management Council for its out-of-cycle review plan.

### Review Process

The out-of-cycle review, although abbreviated compared to the full 2015 Senior Review, followed the same process. ESD issued a call-for-proposal to the QuikSCAT mission team December 4, 2015, and constituted a review panel drawn from the 2015 Senior Review panel, to maximize continuity with the original Senior Review. The mission team submitted an abbreviated proposal on February 26, which included all elements for a successful evaluation: science & technical narratives, a budget proposal and an engineering supplement to assess mission state of health. The Science Panel, comprising the 2015 panel chair and 3 2015 panelists in the relevant discipline, reviewed the proposal in parallel with a subset of the National Interests panel (chair and the 2015 representative from NOAA's National Oceans Service), the technical and cost reviewers. The complete panel (including subpanels) first convened on March 2, to discuss procedures and review assignments. The panel then met for the second and final time on March 15: the preliminary evaluations were reviewed and follow-up topics discussed, then an interactive session with the mission team conducted, immediately followed by the panel's development of findings and a collective evaluation.

### Findings

- Continuation of the QuikSCAT mission beyond its current baseline, until it can overlap with the follow-on ISRO Scatterometer Satellite (ScatScat-1), is valuable for the future of the Ocean Vector Winds climate data record.
- Continuation of the QuikSCAT mission is of very-high utility to the operational users.

- The mission’s state of health is such that it has a medium-high risk of failure before September 2017.
- The mission’s cost proposal is reasonable and in line with historical costs, and should be considered in the next budget formulation cycle.
- Until another capability to calibrate on-orbit Ku-band scatterometers exists, QuikSCAT continuation should be considered in future mission extension reviews.
- Although mission extensions should continue to be reviewed as independent missions, the value of constellations and individual mission contributions to a constellation (e.g. RapidScat/QuikSCAT/ScatSat-1; A-Train; Precipitation) should also be considered explicitly within the Senior Review.

The panel’s evaluation scores for QuikSCAT are:

Table I. QuikSCAT Evaluation Scores

Mission	Science Scores			Numerical Science Score	Adjectival Summary Science Score	Utility Score	Technical Risk	Cost Risk	Conclusion	
	Merit	Relevance	Product Quality						FY16	FY17
QuikSCAT	5.0	5.0	4.5	4.8	Excellent	Very High	Medium-High	Low	Continue/Augment	Continue/Augment

The panel discussed the relative ranking of the QuikSCAT in the context of the mission ranks determined by the full Science Panel in May 2015. Rankings are used to inform and verify the individual evaluations. Although the rankings are somewhat biased by the specializations of the panel members, the result is a 3-tier grouping of high-priority multidisciplinary missions, discipline-focused missions still producing highly-used datasets, and missions producing less-used or degrading datasets. The panel’s consensus is that QuikSCAT should fall within the mid-range missions with highly-used datasets focused on one discipline area, but behind OSTM; this is consistent with the numerical scores assigned by the evaluation.

QuikSCAT, carrying the Ku-band SeaWinds scatterometer, has provided ocean vector wind (OVW) measurements over a wide swath at since 1999. However, in November 2009, the antenna spin mechanism failed; and since then, it has operated in non-scanning mode measuring ocean backscatter ( $\sigma_0$ ) with exceptional radiometric stability. In this mode, QuikSCAT has served as the calibration standard for ocean backscatter measurements, which has resulted in a calibrated OVW Climate Data Record derived from other satellite remote sensors. During fall of 2015, after successfully transferring the Ku-band winds standard to ISS RapidScat, the original plan was to decommission QuikSCAT. This plan was placed on hold after a hardware anomaly in the RapidScat sensor appeared in August 2015, making it unclear whether RapidScat will be capable of transferring the calibration standard to the next Ku-band scatterometer, OSCAT2 on the Indian Space Research Organization’s (ISRO) ScatSat-1 satellite, expected to become operational in late 2016. The objective for the extension of the QuikSCAT mission is limited to cross-calibration with ISS-RapidScat and/or ScatSat-1 to enable continuity of the OVW climate data record. In light of this important scientific benefit, the panel found that the QuikSCAT mission should be extended to September 2017 to give sufficient time for overlap with ScatSat-1.

### Detailed Evaluation Reports

#### Senior Science Panel:

##### **Recommendation:**

- Continuation of project with augmentations to the current baseline

QuikSCAT, carrying the Ku-band SeaWinds scatterometer, has provided ocean vector wind (OVW) measurements over a wide swath since 1999. However, in November 2009, the antenna spin mechanism failed; and since then, it has operated in non-scanning mode measuring ocean backscatter ( $\sigma_0$ ) with exceptional radiometric stability. In this mode, QuikSCAT has served as the calibration standard for ocean backscatter measurements, which has resulted in a calibrated OVW Climate Data Record derived from other satellite remote sensors. During fall of 2015, after successfully transferring the Ku-band winds standard to ISS RapidScat, the original plan was to decommission QuikSCAT. This plan was placed on hold after a hardware anomaly in the RapidScat sensor appeared in August 2015, making it unclear whether RapidScat will be capable of transferring the calibration standard to the next Ku-band scatterometer, OSCAT2 on the Indian Space Research Organization's (ISRO) ScatSat-1 satellite, expected to become operational no earlier than August 2016, at best. The objective for the extension of the QuikSCAT mission is limited to cross-calibration with ISS-RapidScat and/or ScatSat-1 to enable continuity of the OVW climate data record. In light of this important scientific benefit, the panel found that the QuikSCAT mission should be extended to September 2017 to give sufficient time for overlap with ScatSat-1.

#### **Scientific merits**

Excellent

##### **Strengths**

The science benefits of extending QuikSCAT mission can be summarized as follows. First, the QuikSCAT radiometric stability has been proven by more than a decade of successful operation, thus it can provide a "gold standard" in the event of a drift in RapidScat OVW measurement capability. Given the strong scientific justification for the continuity of the RapidScat measurements to mitigate diurnal OVW variability, it is very important to calibrate RapidScat measurements to a high accuracy, and QuikSCAT would provide a unique capability to perform the frequent recalibration required by the RapidScat instrument (as it changes gain). This ensures that the RapidScat backscatter record will be as consistent as possible and will be able to be used more effectively in the ScatSat-1 cross-calibration. Second, QuikSCAT is the only instrument that can provide normalized radar cross section ( $\sigma_0$ ) measurements at exactly the incidence angles and polarizations of RapidScat and ScatSat-1.  $\sigma_0$  is the basic physical ocean roughness parameter required for wind retrievals, which is independent of wind retrieval algorithms. By providing this physical measurement, the consistency of the OVW CDR is improved and extended into 2016-2017, and will also support refinement of RapidScat and Scatsat-1 data processing and wind retrieval algorithms. Third, QuikSCAT is a unique resource for deriving multi-angle, multi-polarization Geophysical Model Functions (GMFs, which are used to convert  $\sigma_0$  to wind in retrieval algorithms) at the incidence angles of the other instruments that reduce these potential systematic biases.

These findings are generally consistent with support found for continued QuikSCAT measurements in the recently commissioned report - 'Evaluating and Extending the Ocean Wind Climate Data Record' produced by members of the international Ocean Vector Wind Science Team. In particular, we strongly concur with the point that there is great benefit in utilizing two separate and independent OVW calibration methods: direct  $\sigma_0$  intercalibration and wind speed intercalibration.

Although QuikSCAT currently operates in non-spinning mode, the radar electronics and the health of the spacecraft were not impacted by the failure of the antenna spin mechanism. This scatterometer has maintained remarkable radiometric stability and has provided the only calibrated source for radar Ku-band normalized radar cross section ( $\sigma_0$ ). It has successfully performed the cross-calibration of ISRO's Oceansat-2 scatterometer and has been continually calibrating the ISS RapidScat since September 2014.

Since the RapidScat has had several transitions between low and high SNR modes since August 2015 and is deemed to be unstable, the panel found that the availability of QuikSCAT is necessary to maintain the calibration of RapidScat and the future ScatSat-1. Because of intrinsic variance in the  $\sigma_0$  measurement due to sampling and geophysical variations, a certain length of overlapping time is needed to achieve a stable calibration. Using data from Amazon rainforest, the mission estimates that one could achieve better than 0.1 dB calibration with an overlapping period of a month and reach better than 0.05 dB for a period of 3 to 6 months. ScatSat-1 is planned to collect data starting August 2016, at the earliest, which only leaves one month of overlap with QuikSCAT, at best, if QuikSCAT were to be decommissioned starting September 2016. This tight schedule would make it difficult for the calibration to be precise within 0.1 dB, even if the ScatSat-1 launch and operation schedule goes as planned. Moreover, the latest news of ScatSat-1's schedule indicates that data collection won't begin until November, precluding any overlap in 2016 at all. Extending QuikSCAT's operation to September 2017 will allow sufficient overlapping data for the calibration precision to reach 0.05 dB, which is desired for a climate data record.

### **Weaknesses**

- a) Quikscat has been in non-spinning mode for well beyond five years and by all accounts the radar sensor and its calibration are exceptionally stable. The panel concurs that the central reason to continue QuikSCAT data collection is to use this radar to carry along calibrations to new sensors that permit a well-documented stand-alone means to sustain an instrument level standard for calibration. However, a possible weakness on the science side is the support for the idea that extended measurements are also leading to land and sea ice monitoring applications. The citations provided to support this are quite limited. If indeed QuikSCAT data from 1999-2009 and/or from 2009-present are leading to additional climate quality measurements or time series, then continuation of these datasets would further strengthen the proposal.
- b) Maybe provide better advertisement of these L1C datasets and their potential uses, at least to the science team.

### **Value of data record and overall data continuity**

The continued observation will allow high-quality calibration of RapidScat and ScatSat-1 scatterometers, which are needed to continue the OVW climate data record.

### **Core mission data product quality and maturity**

Excellent

QuikSCAT mission provides the following data products in its non-spinning mode: backscatter and wind speed. All such data from 2010-2015 have been made publicly available through JPL ftp website. The data were produced and validated as part of the RapidScat calibration activity and will continue to be produced in the lifetime of QuikSCAT. The backscatter measurements are extremely stable. Based on estimates of using Amazon rainforest as a stable target, the drift of QuikSCAT is about 0.02 dB/year with a standard deviation of 0.005 dB/year. In its non-spinning state QuikSCAT oversamples winds along its ground track. The same number of independent measurements originally distributed over a 1,800-km-wide swath are now obtained in a 25-km swath. The resultant averaging leads to individual ocean wind speed measurements with formal random error less than 10 cm/s. An extension of the QuikSCAT mission, in addition to diagnosing trends in RapidScat instrument calibration and allowing cross calibration of ScatSat-1, would also extend the unique QuikSCAT non-spinning backscatter and wind speed data set.

**Relevance to NASA Science Goals:** Excellent**Strengths**

The gain from an extension of QuikSCAT sensor measurements to either Oct 2016 or 2017 is foremost tied to sustaining a long-term climate data record for ocean winds. NASA and its Earth Science Division have significant past and present investments in maintaining and improving ocean observations relevant to climate variability. Ocean wind measured at the sea surface is now a core climate data record and the capability that continued QuikSCAT radar measurements provide are central to creation of independent and well-calibrated ocean vector wind measurements from RapidScat and ScatSat-1 in 2016 and 2017. This mission continuation approach is a viable and cost-effective means to gain the climate data record calibration for these data that are highly relevant to scientific research and ocean weather prediction applications central to NASA goals. Given the recent degradation in RapidScat, the QuikSCAT reference data are likely to increase in importance, lending further support to this pilot NASA ISS earth science mission experiment.

**Weaknesses**

None

**Technical and Cost**

The Science Panel concurs the Technical and Cost sub-panels' findings.

**National Needs**

The Science Panel concurs the National Interests sub-panel's findings.

**National Interests Panel:**

- QuikSCAT is determined to have "Very High Utility"

The QuikSCAT mission is used by NOAA for collecting ocean winds climate data, in this case the NOAA/NESDIS/NCEI/CCOG's globally gridded high resolutions Blended Seawinds product: <https://www.ncdc.noaa.gov/oa/rsad/air-sea/seawinds.html>. This NOAA Blended Seawinds product has multiple societal benefit users such as near-real-time applications in ship routing services as well as in NOAA World Coral Reef Watch; high resolution Great Lakes wind and ice products, Climate Research Weather forecasts, Ocean forecasts, Ecosystem, Engineering (bridge and seawall construction designs), Marine transportation (near-real-time use on ship routing), Wind/wave renewable energy, and Outreach & education. Termination of QuikSCAT data would reduce the spatial-temporal coverage and data quality of the Blended Seawinds product. QuikSCAT and RapidSCAT also support the ocean surface wind product development and validation work that support the NWS operational marine forecasting, warning and analysis. Specifically, the NWS Ocean Prediction Center, National Hurricane Center, Central Pacific Hurricane Center and Weather Forecast Offices with marine responsibilities utilizes satellite ocean surface wind data from missions such as RapidScat in their day-to-day decision making regarding marine wind and wave forecasting, warning and analysis. QuikSCAT also provides an important Ku-band scatterometer calibration reference to provide consistency and continuity of the ku-band scatterometer products started with the NASA Scatterometer (NSCAT) in 1996. The unique orbit of RapidSCAT (non-polar and non-sun synchronous) makes the QuikSCAT calibration reference even more important to make sure we properly characterize the diurnal wind signal and the temporal changes in wind structure that can be observed with the RapidScat orbit.

Technical Panel

**QuikSCAT Out of Cycle Senior Review**

**Technical Review**

<b>PI:</b>	Ernesto Rodriguez	<b>Proposal No.:</b>	N/A
<b>Institution:</b>	Jet Propulsion Laboratory (JPL)		
<b>Title:</b>	QuikSCAT: Proposal to NASA Earth Science Senior Review, 2015 Out-of-Cycle		

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Instrument, Mission Design and Operations, Flight Systems

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**Rationale/Overall Evaluation:**

Low Risk	Medium-Low	Medium Risk	Medium-High	High Risk
			X	

The QuikSCAT proposed mission extension is rated as a Medium-High Risk. The Senior Review Technical Review team has identified two Major Strengths, four minor strengths, no Major Weaknesses and three minor weaknesses that influence the risk determination. **The proposal demonstrates that the operations approach of the degraded QuikSCAT SeaWinds scatterometer (SWS) over the past five years yields backscatter products of sufficient quality to support inter-calibration of the Ku-band ISS-RapidScat. The QuikSCAT proposed mission preserves all remaining propellant for the end of mission orbit disposal.** The outlook for the state-of-health (SOH) of the SeaWinds Scatterometer (SWS) “primary string” has no foreseen obstacles to meeting the life requirements of the QuikScat 1-year extended mission. The LASP Multi Mission Operations center has performed the mission operations for QuikSCAT to date and is well equipped to perform the proposed mission. The current condition of the batteries presents a negligible risk to the first year of the extended mission. Workarounds have been developed and tested in the event of further GPS receiver channel loss. However, the SWS backup string if needed may fail upon activation due to extended radiation exposure, or susceptibility to a common design element plaguing the ISS-RapidScat with erratic gain behavior. The proposed objective for QuikSCAT to provide calibration data for ScatSat-1 is an unlikely 1-year mission achievement as ScatSat-1 science operations will likely be delayed until February 2017. The wideband science telemetry transmitter represents a significant flight system technical risk for the one-year extended mission.

**Strengths and Weaknesses**

**Major Strength:**

• **Instrument**

None

• **Mission Design and Operations**

**The proposal demonstrates that the operations approach of the degraded QuikSCAT SeaWinds scatterometer (SWS) over the past five years yields backscatter products of sufficient quality to support inter-calibration of the Ku-band ISS-RapidScat.** The most important criteria for cross-

platform backscatter calibration are 1) long-duration stability of QuikSCAT scatterometer soundings, 2) observation of the same geophysical target region with minimal time offset, 3) use of identical RF operating frequency, 4) use of identical pulse polarization scheme, and 5) use of matching beam incidence angle. All such criteria are adequately addressed within the proposal. Long-term backscatter stability has been demonstrated by QuikSCAT comparison of post-scan-failure test data with prior data record from its 10-years operational life. The orbits of all three scatterometers allow for less than one orbital period mean latency between observing the same region. QuikSCAT, ISS\_RapidScat, and the future ScatSat-1 all operate at Ku-band with center frequency offsets less than 100 MHz – not a significant frequency difference for observing both Bragg and wave-tilt backscatter. All three scatterometers are designed to operate with interleaved H & V polarized pulses, and the lack of concurrent QuikScat polarization data is indicated to be countered by increased accuracy achieved through the repetitive sampling resulting from the fixed angle/single polarization state of the SWS. The angle-of-incidence offsets between all three scatterometers are significant to data quality; however, interpreting backscatter due to different angles has been mitigated by developing an analysis technique of normalizing the radar backscatter coefficient ( $\sigma_0$ ) to the incidence angle ( $\eta$ ) – this parameter is designated  $\gamma_0$ . Additionally, spacecraft body pointing may be used to align the beam of SWS to RapidScat angles-of-incidence. [[OVWST, “Evaluating & Extending the OW-CDR”, 2/1/16; QuikSCAT(2015-out of cycle), 2/26/2016]

**The QuikSCAT proposed mission preserves all remaining propellant for the end of mission orbit disposal.** QuikSCAT is proposed to remain in a frozen, sun-synchronous orbit through 2017 at 720 km. The proposed mission will not require orbit maintenance maneuvers. Therefore, the maximum capability to lower the QuikSCAT orbit for disposal is maintained.

- **Flight Systems**

None

**Major Weakness:**

- **Instrument**

None

- **Mission Design and Operations**

None

- **Flight Systems**

None

**Minor Strength:**

- **Instrument**

The outlook for the state-of-health (SOH) of the SeaWinds Scatterometer (SWS) “primary string” has no foreseen obstacles to meeting the life requirements of the 1-year extended mission. The plan to turn-off the radar for eclipse and restart post-eclipse involves the uncertainties inherent to high-voltage systems; however, there are no identified prohibitory factors to the 2-year extended mission. The SWS has three subsystems and a shared subsystem for the spacecraft interface: the SWS antenna subsystem (SAS), the SWS electronics subsystem (SES), and the command and data subsystem (CDS). In the event of a failure of the non-rotating components of the SWS there exist potential for backup due to the

design redundancy of the cross-connectable block configuration, however some loss of calibration continuity will occur. [QuikSCAT(2015-out-of-cycle) Sec. 2.2; App. A; App. 7]

- **Mission Design and Operations**

The LASP Multi Mission Operations center has performed the mission operations for QuikSCAT to date, including the responses to all currently identified operational anomalies, and is well equipped to perform the proposed mission. The mission ops center at LASP and the backup MOC at JPL have experience in mission extensions and end of mission planning for several similar Earth-observing missions. [2.3]

- **Flight Systems**

The current condition of the batteries presents a negligible risk to the first year of the extended mission. Failure of a fifth cell would require instrument operation during the second year to end in time to complete spacecraft decommissioning prior to the start of the 2017-18 eclipse season. During a roughly two and a half month eclipse season centered around the winter solstice, failure of 4 of 24 available battery cells has resulted in narrow voltage margins, operational load shedding, and no instrument data collection. If a fifth cell were to fail, the spacecraft could restore positive voltage margin during eclipse by retreating to a spin-stabilized “emergency mode” which is described as robust. While not explicitly stated in the proposal, this discussion assumes the spacecraft cannot survive eclipse season if a sixth cell were to fail.

Although both Primary and Secondary GPS receivers have experienced failures, the primary GPS receiver, which has use of 6 channels for processing GPS Satellite Vehicle (SV) signals, has been in constant use over the lifetime of the mission. There are operational workarounds developed and tested, so complete loss of the remaining GPS receiver does not pose a technical risk. [Section 2.1, item 1; Sec 2.1]

**Minor Weakness:**

- **Instrument**

The proposal does not address uncertainties for the SWS backup string state-of-health (SOH) relating to radiation degradation and susceptibility to RapidScat failure modes. The instrument has been configured to the primary chain for its entire 15-years on orbit with the result that the backup units have never been activated to assess SOH. The ability of the backup string to startup and sustain operations cannot be directly assessed. Components in the off-state experience the same radiation exposure as those in the on-state and some may be more susceptible to degradation due to having a lesser degree of trapped-charge release and lattice annealing than the warmer on-state electronics. In addition to the radiation considerations, when assessing the likely SOH of the SWS backup string, two opposing data points from operational experience are relevant: (1) the demonstrated long life of the SWS primary string, and (2) the early-life failure of the RapidScat. The SWS has one-to-one design commonality with the RapidScat units experiencing early-life failure. It is noted that the nature of the RapidScat failures allow for continued operations, therefore, the uncertainties about SWS backup capability do not seriously undermine confidence that a meaningful degree of the SWS redundancy will be available in the event of contingency during the mission extension. [QuikSCAT(2015-out of cycle, 2/26/2016; Glen Havens, RapidSCAT Anomaly Status, 11/4/2015)]

- **Mission Design and Operations**



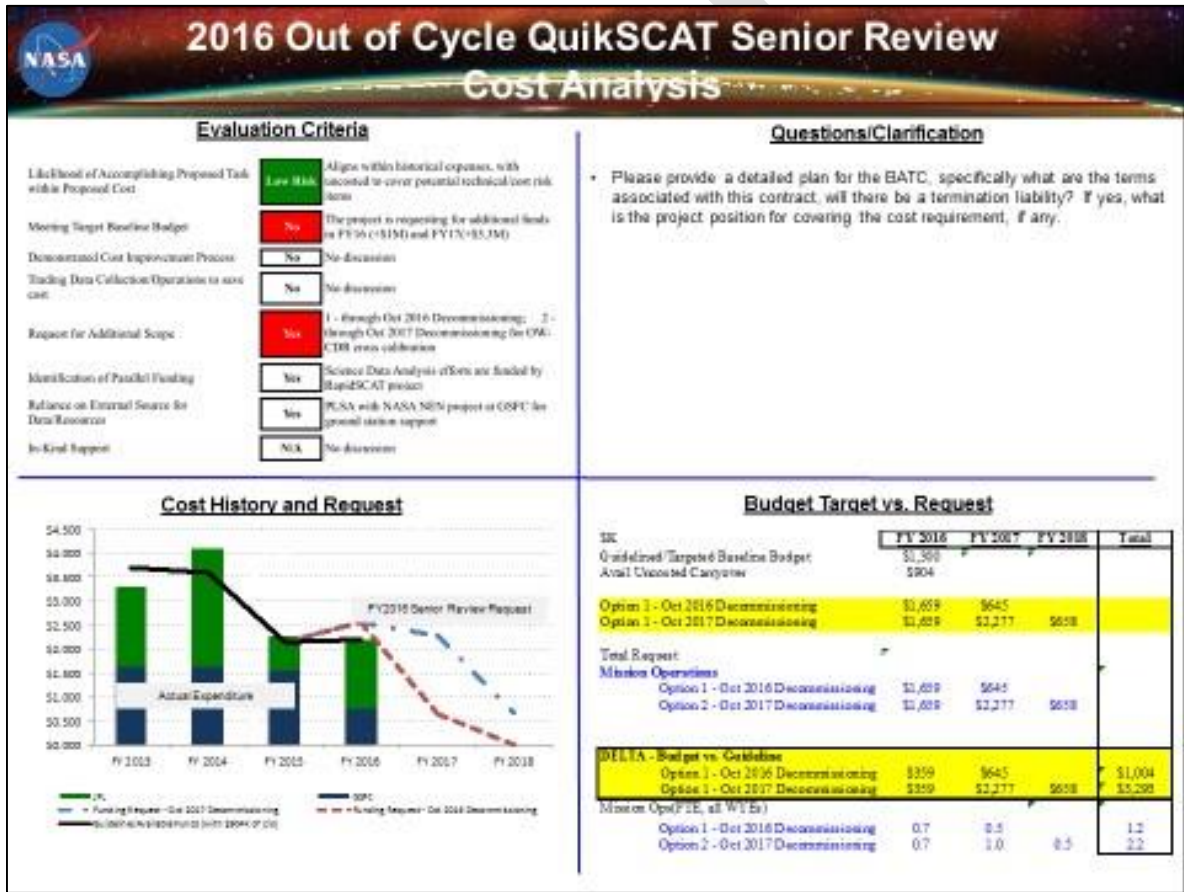
The proposed objective for QuikSCAT to provide calibration data for ScatSat-1 is an unlikely 1-year mission achievement as ScatSat-1 science operations will likely be delayed until February 2017. The proposal describes a launch date for ScatSat-1 “as early as April 2016” at a time when the European Space Agency reports a launch date of July 2016. The Senior Review Technical Panel’s conservative estimate for the beginning of ScatSat-1 science operations (four months after launch) is thus November 2016, and not “August 2016” as indicated in the proposal. This start date for ScatSat-1 is perilously close to the annual eclipse period for QuikSCAT and coordinated calibration campaigns will likely be delayed until early February 2017. This delay increases the risk of further QuikSCAT NiH2 battery degradation due to exposure to the 2.5 month seasonal eclipse period during the winter of 2016-17.

- **Flight Systems**

The wideband science telemetry transmitter represents a significant flight system technical risk for the one-year extended mission. The primary failed after 7 years of use. The backup will reach 10 years of operation during the first year mission extension, and its failure would end the science mission. There are apparently no trends or events to serve as a harbinger of failure for the remaining transmitter, therefore it is hard to assess the probability of failure of this backup during the extended mission. [Section 2.1, item 2]

## Cost Review

Cost analysis was done on the QuikSCAT out-of-cycle extension review to see if requested amounts were in line with historical costs and future year assumptions. The analysis revealed that the labor, travel and procurement requests were reasonable. JPL labor (WYE) and associated rates were in an expected range. While uncosted carryover and FY16 funding of \$1.3M are available to help cover these expenses, under either decommissioning scenario, additional funding will need to be requested as a FY18 PPBE overguide. Due to the reasonable nature of this funding request, it is recommended that this request goes forward in the Project's FY18 PPBE request.



NASA **2016 Out of Cycle QuikSCAT Senior Review**  
**Cost Analysis**

Contributors to Higher Cost	Contributors to Lower Cost	Factors potentially affecting MO&DA success
<ul style="list-style-type: none"> <li>&gt; <b>Option 2:</b> Oct 2017 QuickSCAT EOM (operates through RapidScat EOM)</li> </ul>	<ul style="list-style-type: none"> <li>&gt; <b>Option 1:</b> Oct 2016 QuickSCAT EOM (2mo overlap w/ ScatSat-1)</li> <li>&gt; Reduced flight system capabilities                             <ul style="list-style-type: none"> <li>&gt; QuickSCAT in non-spinning mode (Nov'09)</li> <li>&gt; RapidScat intermittent sensor gain/stability issue (Aug'15)</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>&gt; Redundant QuickSCAT S/C</li> <li>&gt; QuickSCAT S/C Anomalies:                             <ul style="list-style-type: none"> <li>&gt; GPS: only 6 of 12 channels on Primary operate</li> <li>&gt; Wideband science telemetry xmtr: Using backup after primary failure (Jul'07)</li> <li>&gt; PCU: Backup failed (Nov'08) but recovered (Jun'09)</li> <li>&gt; Shorts in 4 battery cells</li> </ul> </li> </ul>



**MOR&DA Cost Drivers**

	Daily Data Rate, GB/day	Science Team Size (PPS/Cols)	Inst Cells	# of Instruments
RapidScat	6.4	25	1	1
QuickSCAT	21.6	20	1	1

NASA **2016 Out of Cycle QuikSCAT Senior Review**  
**Cost Analysis**

**Finding Summary**

- Both options utilize existing funding of \$1.3M to absorb some budgetary impact.
- Very good correlation between proposed cost to proposed workforce number.
- Labor rate and JPL plan align well with other operating missions.
- Other costs, such as procurement and travel also appear reasonable.
- Recommend allowing either request to go forward and be included as an overguide request in the 2018 PPBE process.