Pre-Aerosols, Clouds and Ecosystems - Ocean Ecology Spectrometer (PACE-OES)

~ Concept Presentation ~

Comparison of OES Cost Results: 3 vs 6 SWIR bands

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OES Study Objective

- **The objective of the Ocean Ecology Spectrometer (OES) study was to adapt the IDL's 2009 design for OES to incorporate 3 additional SWIR bands for cloud measurements**
  - The original ORCA design included 3 SWIR bands for ocean measurements, as well as a red and blue channel
- **The adaptation of OES was intended to minimize changes tot the optical bench footprint, and to minimize changes to the mechanisms**
  - Other design changes beyond what was necessary to accommodate the 3 additional SWIR channels were inhibited in order to capture the cost impact of that change
  - The primary exception to that was to move the radiator for electrical boxes to the outside of the structure, and to move those associated electrical boxes to that side of the frame, for a more efficient thermal subsystem
- **The outcome of the study was a modest change to the instrument configuration from the OES 2009 design**
  - A comparison of the instrument design and resource needs is shown in this document
- **To prepare an accurate cost estimate between the 2 versions of this instrument, the IDL team recosted the 2009 configuration with the same schedule and build assumptions as the 2011 design**
  - That comparison is also shown in this document

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Resource Needs Comparison

all estimates shown are CBE; no contingency has been applied

Instrument Assemblies	Total Mass	Total Power (Average)	Total Data Rate
2009 OES	137.2 Kg	131.2 W (40W Avg Heater Power)	Average Data Rate to S/C SSR = 4.35 Mbps
2011 OES	165.6 Kg	144.6 W (includes 43 W Orbital Avg Heater Power)	Average Data Rate to S/C SSR = 4.482 Mbps

For more information on:

- details on the **mass** rack-up, please see the mass model for each instrument configuration
- details on the **power and telemetry** rack-ups, please see the point design summary (PDS)
- how to use a cost estimate that is based on a point design with Current Best Estimates **(CBE)** of mass, please see the Cost Assumptions document

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OES Cost Comparison*

Baseline OES		Enhanced Cloud Aerosol OES	
FY12$	$250M	FY12$	$260M
FY$	$286M	RY$	$297M

***Baseline OES was modified to incorporate 3 additional SWIR bands for cloud measurements**

Number of fully integrated flight units to build and cost :

Fully Integrated Flight Units	**1**
Fully Integrated Flight Spare Units	**0**
Fully Integrated Engineering Test Units (ETU)	**1**
Fully Integrated Engineering Development Units (EDU)	**Partial**

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Cost Models

- **The IDL adapted the 2009 mass model to produce the 2011 mass model**
  - The mass model is also known as the Master Equipment List (MEL)
  - We reflected all the changes to the instrument to incorporate the addition of the 3 cloud SWIR detectors in all subsystems
- **The IDL captured the customer team's cost assumptions for 2011**
  - These new build and schedule assumptions were applied to the 2009 cost model for OES
  - We have learned that if the instrument development schedules are not identical, there are artificial cost differences
- **The IDL recosted the customer's 2009 mass model for OES using the SWIR detector description from the 2011 study**
  - We could not maintain the 2009 purchase approach for the SWIR detectors because the XXXXX vendor no longer produces that product line
  - We recosted all the detectors parametrically using SEER-H Spyglass for both versions of the instrument
  - For the cloud channel detectors, we used the grassroots cost estimate in calculating the instrument total because these performance requirements can be readily met with a COTS purchases of parts produced in volume for the communications industry – the parametric estimate is shown in the cost results for reference
  - A parametric estimate for the ocean channel detectors was felt to be more representative of the development costs to meet the more challenging performance requirements
  - The OES 2009 cost model has the same detector set as the 2011 OES – without the 3 SWIR cloud detectors that were the new addition to the instrument

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Instrument Development Schedule applied to Both Versions

Instrument Life Cycle

Phase A Start	
Phase B Start	7/2013
Instrument PDR	5/2014
Instrument CDR	5/2015
Instrument Production End (SIR)	11/2016
Payload Delivery to Observatory I&T	11/2017
Launch Readiness Date	12/2018

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Build Approaches applied to Both Versions

Number of fully integrated flight units to build and cost (see Note 1)

Fully Integrated Flight Units	1
Fully Integrated Flight Spare Units	0
Fully Integrated Engineering Test Units (ETU)	1
Fully Integrated Engineering Development Units (EDU)	Partial

Build Assumptions (see Note 2)

Out of House

Cost Assumptions (see Note 3)

60/40 Real Year CBE

Class of Mission (see Note 4)

Class B Mission with Class S electronics

Notes:

1. This was the same build approach used in the 2009 study, and it was maintained for the recost of OES
2. The 2009 cost results for OES used in-house labor rates; the recosted model for 2009 OES used out-of-house labor rates to be consistent with 2011 OES
3. The 2009 cost results for OES were done in FY09 constant year dollars; the recosted model for OES 2009 used Real Year dollars to be consistent with OES 2011
4. The 2009 cost results for OES were also costed with Class S parts, and that was maintained for the recost of OES 2009

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Instrument-Level Wraps used for Both Versions

- Instrument-level wraps specific to OES were generated during a collaborative sidebar with the customer team
- These wraps are applied to the parametric estimate of the instrument to account for significant activities completed after the instrument is fully integrated
- These wraps were also applied to the recost of the OES 2009 model

Instrument Level Considerations	Wraps
Ground Support Equipment (GSE) that is instrument-specific (that is, cannot be readily adapted from general purpose GSE)	5%
Environmental testing at the Instrument Level	5%
Component level flight spare components	10%
Engineering Test Unit (ETU)	10%
Instrument to S/C Integration and Test (typically included in WBS 10.0)	was not applied
Center Management & Overhead (CM&O), although this may not apply to developments or AOs	was not applied

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IDL Cost Products for OES

- PACE_OES_MEL_Final_update.xls
  - The IDL's edit of the 2009 OES MEL to represent the 2011 configuration for OES
  - The cost assumptions tab in this MEL was used for both cost models
  - There are other tabs in this spreadsheet that capture the cost assumptions for the optics, the detectors, FSW, and FPGAs
- PACE-OES_ParamEst_091611.ppt
  - A powerpoint summary of the cost model for PACE-OES and the recosted OES model
- PACE_OES_Paramest_091611.xls
  - Static cost product for the OES cost model as well as the 2011 recost of OES
  - This spreadsheet shows the lifecycle cost estimate for every line item in the MEL
  - If adjustments are made to this spreadsheet, the cost is not automatically recalculated unless the customer encodes the summary cells
  - See the directions on Price-H Spreadsheet Adjustments.doc that accompanies the cost products
- OES 2009-2011 Cost Comparison.ppt
  - Compares the engineering resource needs and cost estimates (this presentation)

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Supplemental Cost Documents

In the final report, there are additional cost reference documents for the customer's use

- **PRICE-H Spreadsheet Adjustment.doc**
  - Provides guidance on how to encode the cost product and adapt it to adjust for specific changes in line item quantity and costs
  - Explains in detail how the instrument level wraps have been applied to the parametric cost estimate, and demonstrates how to adjust those when there's been a change to the detailed parametric estimate
- **Customer Cost Input Sheet**
  - A template that the customer can use for follow-on costing request through the Science Proposal Support Office (SPSO)
  - As the IDL support for a 1-week study typically includes a cost estimate for a single instrument configuration, additional iterations our outside our scope of work
  - Please contact Bill Lawson/605 to request follow-on work at 301-286-3431 or William.M.Lawson@nasa.gov
- **FPGA Firmware cost scheme**
  - This scheme was derived in 2007 to capture the labor involved with developing the firmware for Field Programmable Gate Arrays (FPGAs) for spaceflight instruments
  - While the parametric cost estimate includes the cost of procurement of the flight FPGA as well as integration and testing of that chip within the printed circuit board, there is additional labor that is not captured in PRICE H that is addressed with this scheme
  -

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The following charts provide reference information on the IDL's cost product and our parametric cost modeling tools

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IDL Point Design Estimate & Cost Risk

- The IDL Cost Estimate is a Point Estimate based on the single point design of the instrument
- The point design that the IDL derives in a 1-week study is An engineering solution, but not necessarily THE solution that will be implemented for flight
- The point estimate is described by the IDL in the MEL in terms of Current Best Estimate (CBE) of mass and materials, and represents a single estimate among a range of feasible possibilities
- Cost risk analysis attempts to address the risk that the eventual outcome of the parameters may differ from the CBE selections made at the conceptual design phase of pre-formulation
- Cost risk capabilities within the parametric cost modeling tool allow a range of input values to be entered to generate a range of cost outcomes
- Cost risk simulation is performed using well known sampling techniques (e.g. Monte Carlo simulation) of the parameter ranges resulting in a Probability Distribution Function (PDF) of possible outcomes, also known as a Density Curve
- PDF can also be represented as a Cumulative Distribution Function (CDF), also known as an S-Curve to provide a graphical representation of the possibilities of various cost outcomes
- Cost risk analysis takes additional labor and is beyond a 1-week IDL study, and is not recommended for the initial instrument conceptual design, but will be necessary for proposal development

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Using your Point Design Estimate

- Often, early formulation Managers must get their designs into a cost box during IDC studies, before cost risk analysis can be performed
- Doing this requires trades and descopes against science performance, so descopes should be minimized whenever possible
- However, failure to fully understand the difference between a point design cost estimate and a probabilistic cost estimate can result in unexpected sticker shock later
- NASA desires probabilistic cost estimates at the 70% Confidence Level (CL) so that our endeavors have a 70% chance of succeeding without a cost overrun
- The point design cost estimate is ALWAYS well below the 70% CL, so Managers should realize this when working with a point estimate and use a rule of thumb multiplier to act as a placeholder for the extra money that will be required for a 70% CL price
- A reasonable multiplier is 1.5 X CBE point design cost, to use as a placeholder until you can complete the full cost risk analysis, when checking to see if your price is "in-the-box"
- This will allow Managers to make trades/descopes during very early engineering formulation, such as IDC studies, AND avoid sticker shock when the eventual cost risk analysis is completed, which requires a fair amount of design maturity to be developed first

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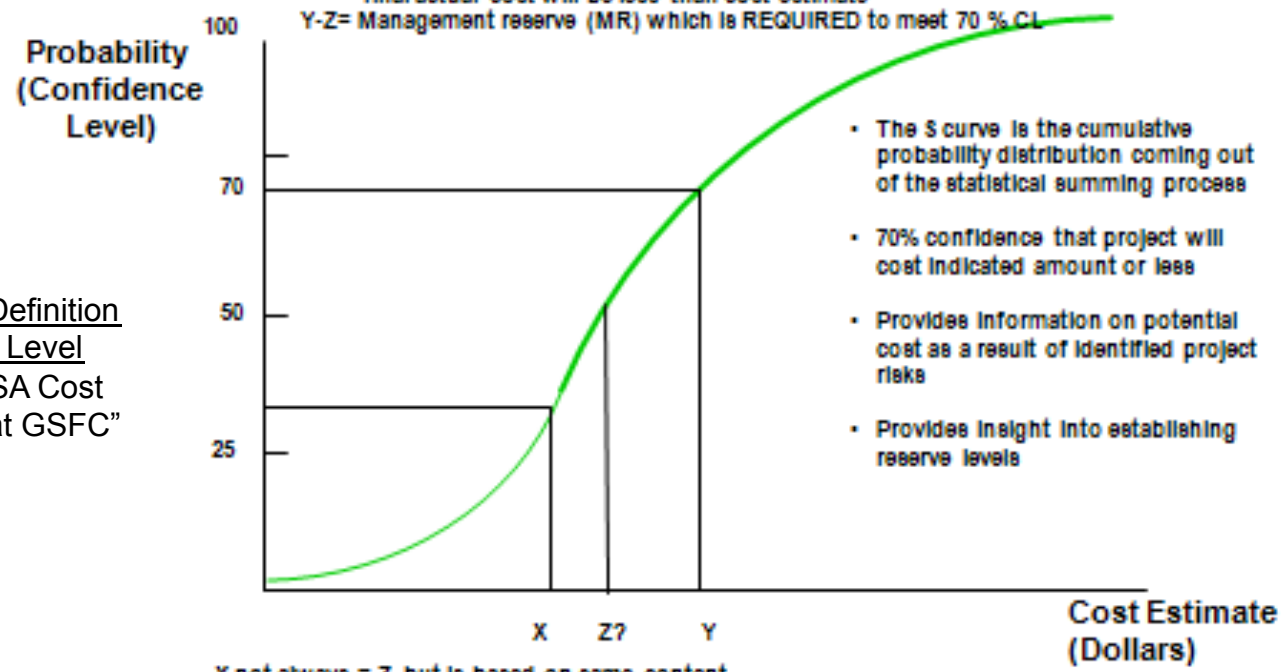
Cost Confidence Level

Definition of Confidence Level (CL)

X = Point estimate
Z = Project requirement
Y = Cost estimate where there is a 70% chance that final actual cost will be less than cost estimate
Y-Z= Management reserve (MR) which is REQUIRED to meet 70 % CL



- The S curve is the cumulative probability distribution coming out of the statistical summing process
- 70% confidence that project will cost indicated amount or less
- Provides information on potential cost as a result of identified project risks
- Provides insight into establishing reserve levels

X not always = Z, but is based on same content

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Selected Slide, Definition of Confidence Level (CL), from "NASA Cost Risk Workshop at GSFC"

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Technology Development is a Recognized Risk

- **One of the 5 Contributing Factors to Cost Overruns and Schedule Delays from the NASA Instrument Capability Study (NICS) report is that Technology development is risky and unpredictable**
  - When programs optimistically assess the technology readiness level, they are underestimating the labor and time to complete the design and analysis of component specifications, as well as to qualify that new component or subsystem to all aspects of the relevant flight environment
- **A Technology Readiness Level (TRL) assessment applies to new and existing technology capability**
- **New Technology**
  - When developing new technology, you will encounter unknown unknowns that may change the materials, the electrical or mechanical interface, or the overall implementation approach – these changes impact other subsystems, and cost time and money
  - To defend the performance benefits of implementing new technology, not only should the science traceability justify the resource investment, but a thorough and accurate technology development plan will retire perceived risks
- **Existing Technology**
  - When developing a custom build of previously flown functionality of technology is not new, there is still a considerable amount of labor involved to derive the performance and operational requirements for the new design
  - Aerospace technology and capability utilized in a new configuration will require custom hardware, procedures, and GSE, so again, an accurate estimate of the current state of development is necessary to capture the labor required to fully mature the custom design to flight readiness

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Spares Approach

Number of fully integrated instrument-level units to build and cost:

- **Flight Units**
- **Flight Spare Units** **(parametrically identical to the flight and prototype units)**
- **Full Prototype Unit** **(unique to this study)**

Please note that the Instrument Design Lab (IDL) rarely has the opportunity in a 1-week study to address component or assembly level spares. Sparing is assessed at the instrument-level. The cost for component-level spares is captured as 10% of the total instrument cost. In addition, the cost for not-fully integrated ETUs is captured as 10% of the total instrument cost.

Definition of ETU and EDU:

- **Engineering Test Units (ETU)** **(protoflight)**
  - Can be tested to flight levels
  - Can be flown
- **Engineering Development Units (EDU)** **(prototype)**
  - Not built to flight levels
  - Can <u>not</u> be flown

The IDL will automatically assume an EDU is developed for all subsystem assemblies (without an EDU, there are cost impacts to going straight to flight unit production, because more risk is incurred). We will not assume that an integrated EDU of the entire instrument is developed, rather, that EDUs for subassemblies are built and tested. If the scale of the instrument is large (e.g. a segmented telescope or multiple focal plane assemblies), we may assume only a partial EDU is developed for a portion of subsystem hardware.

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Your Parametric Cost Estimate is a Complete Lifecycle Estimate

- **Your parametric cost estimate is provided in a powerpoint presentation as a summary**
- **It is also included as a static spreadsheet in MS Excel format**
  - By static, we mean it is not encoded to re-sum any changes you may enter
  - This spreadsheet is saved to the Cost Model folder in the final report
- **Line item costs for individual components in the cost product spreadsheet are lifecycle cost estimates of the total financial burden to the government to fully develop and qualify that component from 'cradle to grave'**
- **Lifecycle costs**
  - Not only include the cost to fabricate (or procure) the component
  - But also include all the non-technical and technical systems engineering and project management labor to
    - design the part
    - analyze it
    - derive and document the specifications for the part
    - produce the engineering drawing
    - track the part specification in configuration management
    - procure and receive the part
    - validate the performance
    - support the design process with design reviews, ECN/ECRs, etc.
    - Data management, QA, Reliability, etc.

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Your Parametric Cost Estimate is a Complete Lifecycle Estimate

- **There are some items in the mass model of your conceptual instrument that the IDL team will indicate as purchased components**
  - Purchased components include such devices as temperature sensors, thermal paint, and mechanism motors, for example
  - These are assumed to be commercial off the shelf (COTS) purchases of heritage flight components
- **There is a design and engineering 'wrap' that the cost modeling software will add to purchased components to ensure that a full lifecycle estimate is produced**
  - The cost to the government is not limited to merely the purchase price
  - Technical labor is required to perform analysis and modeling to ensure that this specific COTS part is sufficient, and to document the performance specifications, as well as to receive, test, and integrate the part
- **Lifecycle expenses related to purchased components:**
  - When a component is assumed to be purchased from a vendor (i.e. a vendor quote has been provided), an additional line item is added to the parametric cost model to account for the design and engineering effort to
    - verify the specifications for that part will meet the overall system performance requirements
    - document the specifications for the part in a fabrication drawing
    - track the part specification in configuration management
    - procure and receive the part
    - validate the performance
    - support the design process with design reviews, ECN/ECRs, etc.
    - Data management, QA, Reliability, etc.

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Accounting for I&T Costs

- **All SubAssembly-Level I&T Costs are included in the Parametric Lifecycle Cost Estimate**
  - The final cost product will include I&T line items for each subassembly and assembly to account for the labor and hardware to accomplish the following tasks associated with instrument development:
    - write and execute procedures to integrate two or more subsystems/elements
    - write and execute procedures to verify electrical and structural interfaces and specification compliance
    - design and procure or fabricate GSE for the I&T sequence (e.g. power supplies, o-scopes, logic analyzers), but not the instrument-specific MGSE or EGSE which most instruments eventually require
    - these are sub-instrument I&T events, not the instrument-level I&T event

- **Instrument-Level I&T**
  - Instrument-level I&T is not estimated directly with PRICE H
  - It is typically assumed to be a percentage of the total parametric (PRICE H) instrument cost, and is broken down into the categories shown on the following page, which can be scaled based on the complexity and maturity of the instrument

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Instrument Level Cost 'Wraps'

- The following 'wraps' are added to the parametric cost estimate of the instrument to account for the full instrument-level lifecycle costs to the center
- These placeholders are based on historic data to ensure that the final cost estimate is a complete lifecycle cost estimate to fully qualify and integrate at the instrument level
- The IDL will work with the customer team to tailor these wraps to capture instrument-specific drivers or handicaps that may increase or decrease these expenses

Instrument Level Considerations	Typical Wrap
Ground Support Equipment (GSE) that is instrument-specific (that is, cannot be readily adapted from general purpose GSE)	5%
Environmental testing at the Instrument Level	5%
Component level flight spare components	10%
Engineering Test Unit (ETU)	5%
Instrument to S/C Integration and Test (typically included in WBS 10.0)	5%
Center Management & Overhead (CM&O), although this may not apply to developments or AOs	Is specific to each NASA Center

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