Joint ISPA/SCEA Conference 2011

Overcoming Challenges in Estimating Advanced Technology Programs

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Agenda

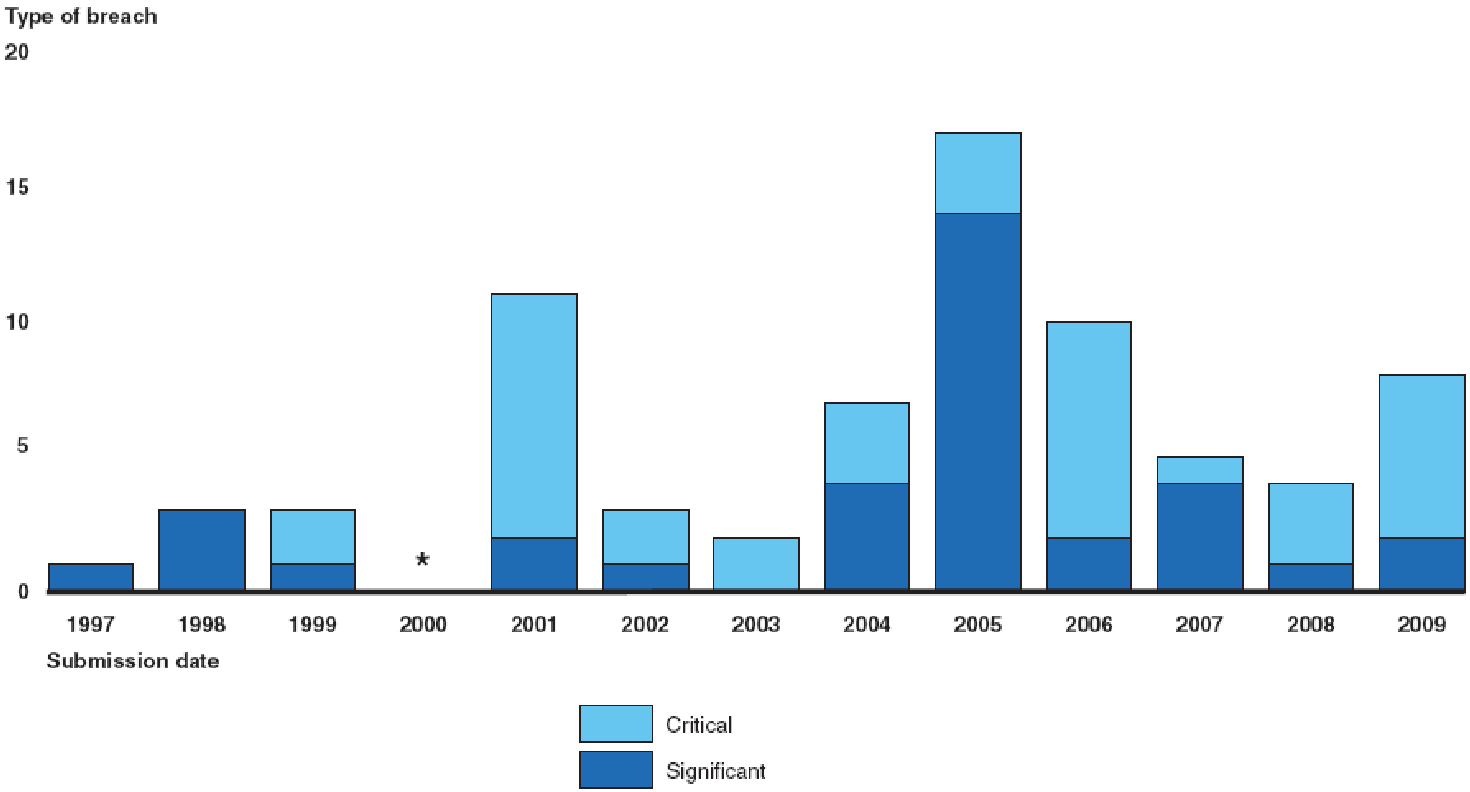
- **Challenges in Estimating Advanced Technology Programs**
- **Best Practices**
- **Structuring Cost Estimates for Advanced Technology Estimating**
- **Analysis of Alternatives Demonstration**
- **Conclusions**

Challenges in Estimating Advanced Technology Programs

- **Databases often don't exist, technology may be developed 10-15 years in the future**
- **Data-Driven estimating concepts may not apply**
- **Extrapolating past program experience by analogy may not be appropriate**
- **Cost Estimating Relationship development**
  - **Independent variable values (i.e. performance values and technical characteristics such as weight, thrust, and speed) are highly uncertain**
- **Level of confidence in cost and schedule – trends in cost overruns a major concern!**

Trends in DoD Cost Overruns
Nunn-McCurdy Cost Breaches

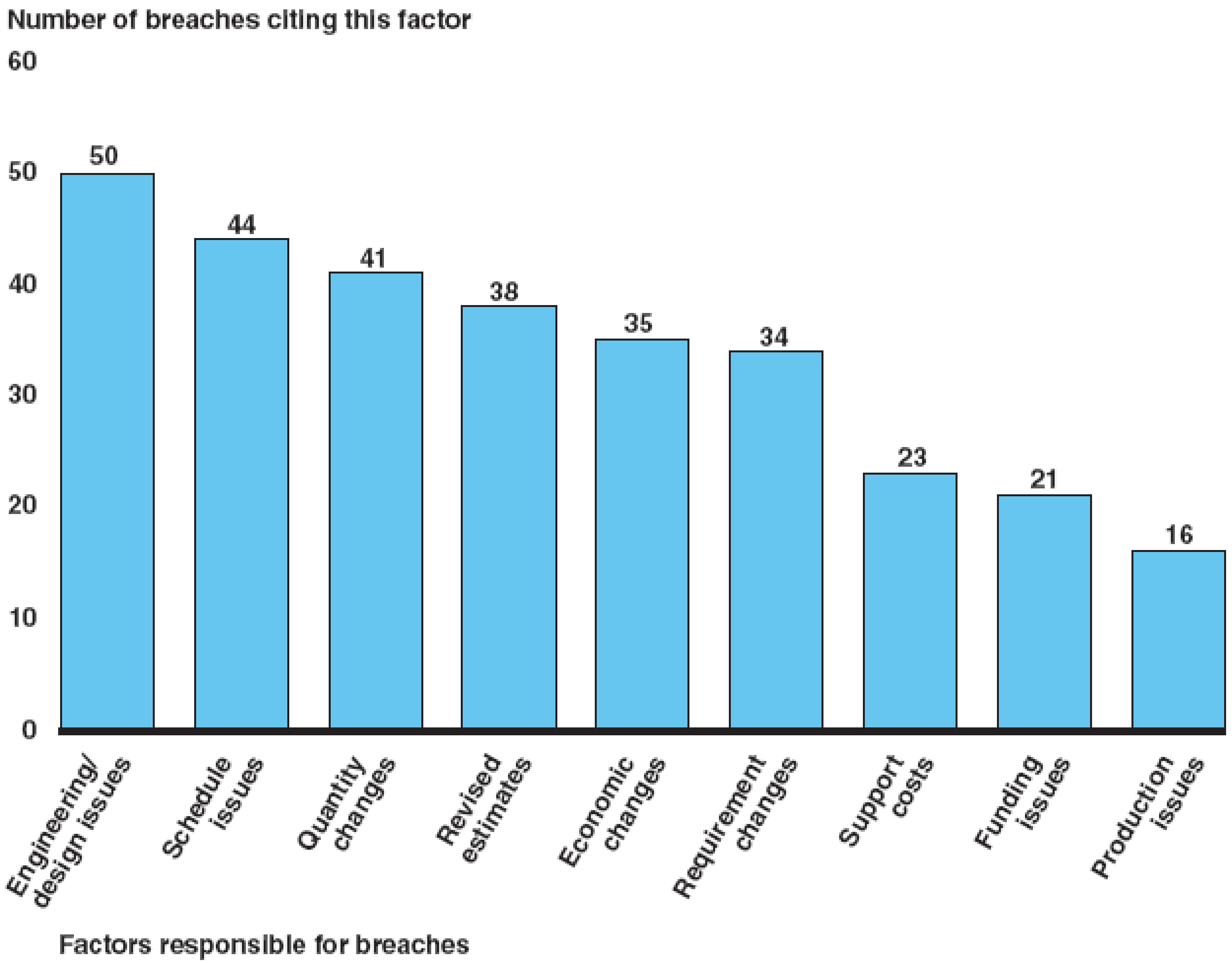
Figure 1: Critical and Significant Breaches by Calendar Year, 1997-2009



Source: GAO analysis of DOD data.

Since 1997, there have been 74 Nunn-McCurdy breaches involving 47 major defense acquisition programs.

Factors Responsible for Nunn-McCurdy Cost Breaches



Source: GAO analysis of DOD data.

Engineering Design Issues for ATPs – A Major Factor

- **GAO found that Engineering Design issues were most cited as a factor for Nunn-McCurdy cost breaches.**
- **GAO study recommended early and continued systems engineering analysis…**
  - **Specifically "robust AoAs and preliminary design reviews (PDR)….ensure that new programs have a sound, executable business case that represents a cost-effective solution to meeting warfighters' needs.**
- **However, while there are SPDR/CCDRs for R&D programs of record (but not for ATPs) this presents challenges for estimating when little data is known.**

Correct Cost Estimating Approach for ATPs' is a Critical Factor!

Approaches to Estimating ATPs

- **Subject Matter Expert**
- **Delphi Technique**
- **Cost Estimating Relationships**
- **Commerical based parametric models**
- **DoD based parametric models, for example**
  - DASA-CE Performance Estimating Relationships (PER), which use mission inputs to estimate costs of pre Milestone A programs.
  - Capabilities Knowledge Base (CKB) – housing over 50,000 data points

Types of Early State Estimates used for ATPs

- **Analysis of Alternatives –** Is proposed technical baseline cost-effective against other competing alternatives in meeting both performance and cost?
- **Cost Realism –** Are the performers bidding within an accurate range based on past experience?
- **Data Driven Estimating –** Are the performers bidding based on appropriate, traceable historical data points if applicable?
- **Independent Cost Estimate (ICE)** – Using the performer's technical configuration, what does an completely independent look say about the performer's bid?
- **Risk Analysis** – Is the bid over conservative, what is the risk profile and how much cost exposure can we absorb?
- **Schedule** Estimating – Can we really do the job within the schedule constraints?
- **Growth Estimating** – What other configurations, materials or technologies might we consider?

Best Practices for Estimating ATPs

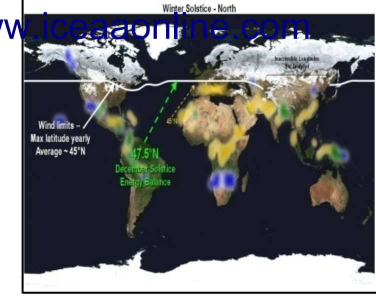
- Use more than one estimating approach to "triangulate"
- Dig into the technical and cost volumes to derive the configuration, technology, weight statement, rates/overheads
- Ask the engineers who are subject matter experts in each area to discuss the other qualitative factors about each performer.
- Conduct interviews with each SME to derive inputs such as requirements stability, engineering complexity, integration and other critical factors
- Hold meetings remotely so everyone can see your desktop and no one has to leave their desk
- Make sure your estimates are well documented!

Key Documents and Parameters

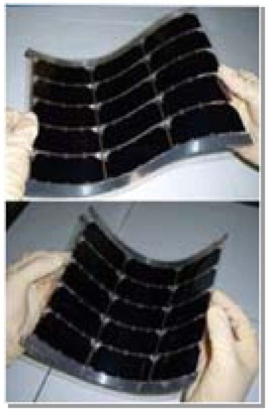
- OV-1 – High Level Operational Concept Graphic
- Understand the technology
- Understand the configuration
- Weight statements
- Analogous systems, prior history
- Statements about the engineering team, CMM level
- Software configuration, Source Lines of Codes/Function Points
- Direct Rates, Overhead, G&A and Fee
- Work Breakdown Structure
- Material/Labor split
- Major Subcontractor's Equipment

Advanced Technology Estimating Demonstration
Analysis of Alternatives
High Altitude Long Endurance (HALE) UAV

HALE UAV Program Overview

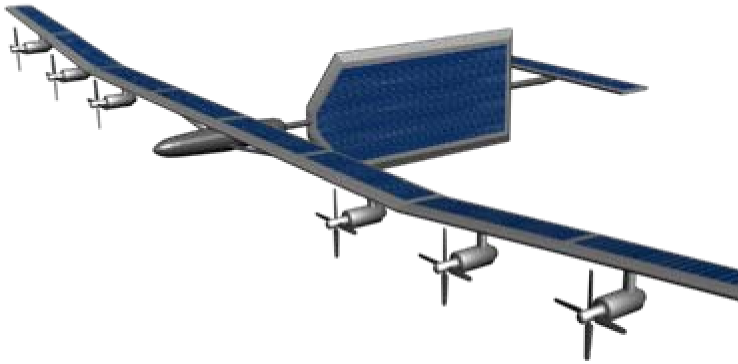


- **Program Goals and Objectives**
  - Develop a HALE UAV that can maintain a 1000 lb, 5kW payload on-station continuously for 5 years
- **Technical Challenges**
  - Closing on the Energy Cycle: Harvesting & Storage
  - Structural Integrity & Control System Coupling
  - Reliability
- **Technical Approaches / Advanced Estimating Challenges!**
  - Solar Electric (Photovoltaic) Energy Collection
  - Fuel Cell / Battery Energy Storage
  - Single System vs Airborne Docking/Replacement
  - Satellite Design Paradigm for Reliability
  - Redundancy for Planned Degradation
  - Few Moving Parts (e.g. Propulsion as Flight Control)



HALE UAV Advanced Technology Concept
DARPA VULTURE

- **Vulture Requirements**
  - **Payload: 1000 lbs, 5kW**
  - **Reliability: 5-years on station, with design loiter speed to allow 99+% time-on-station**



Notional Vulture

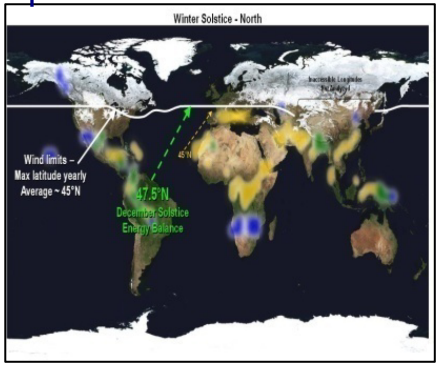
- **Vulture will shatter previous record**
  - **Voyager Endurance 9 days**
  - **Vulture Endurance >1800 days**

- **Vulture Challenges**
  - **Increasing reliability of moving components**
  - **Closing the energy cycle**
    - *Collecting and storing energy (solar)*
    - *Reliably replenishing (fueled)*
    - *Efficient propulsion*
  - **Aero-structure efficiency to increase endurance**
  - **Material degradation for long-term stratospheric flight**

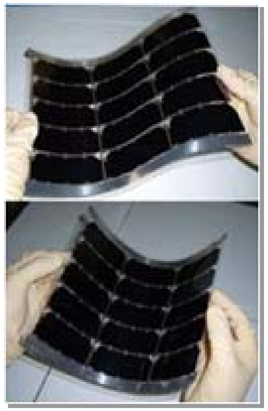
Voyager

Vulture HALE UAV Competing Design Alternatives

Vulture UAV Analysis of Alternatives



- **Vulture Cost Estimating Requirement**
  - Perform an early stage, pre-milestone A Analysis of Alternatives estimate to determine the cost/effectiveness of Vulture against Global Hawk and Global Observer
  - Detailed data on Vulture is not developed at this point
  - Existing data is very high level
  - High risk, Advanced technology must be developed by DARPA



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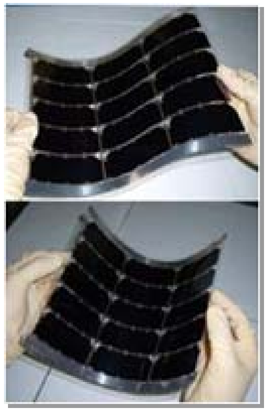
Vulture UAV Estimating Challenges

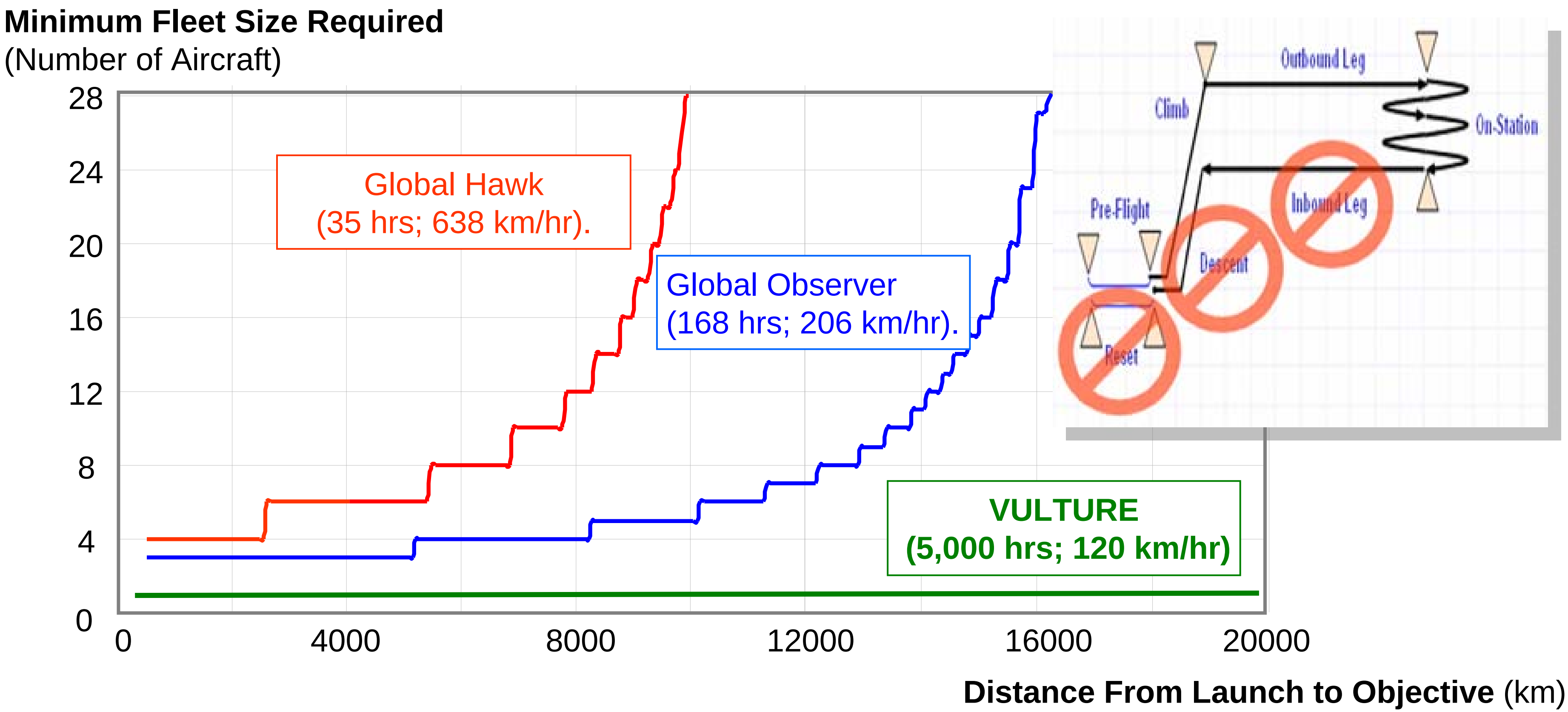
- **Responding to Advanced Estimating Challenges**
  - New cost estimating paradigms are required especially for solar electric and fuel cells.
  - Current technology cannot support a 5 year HALE mission
  - The real issue is how to estimate these advanced technologies where no existing data exists



Best Practices – Modeling of the HALE UAV AoA

- **Model the configuration (weight statement and performance characteristics) using a parametric approach.**
- **Consider modeling high value vendor items as "make" for that particular vendor using the appropriate parametric modeling.**
- **Model software consistent with the Technical Volume. If possible, perform an independent software size analysis.**
- **Consider making submission of *tailored* parametric data forms a required proposal deliverable for information not contained within Technical/Cost volumes or attainable from SME interviews.**

Establishing the Performance Characteristics of the HALE AoA

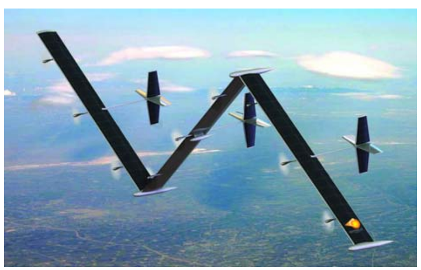


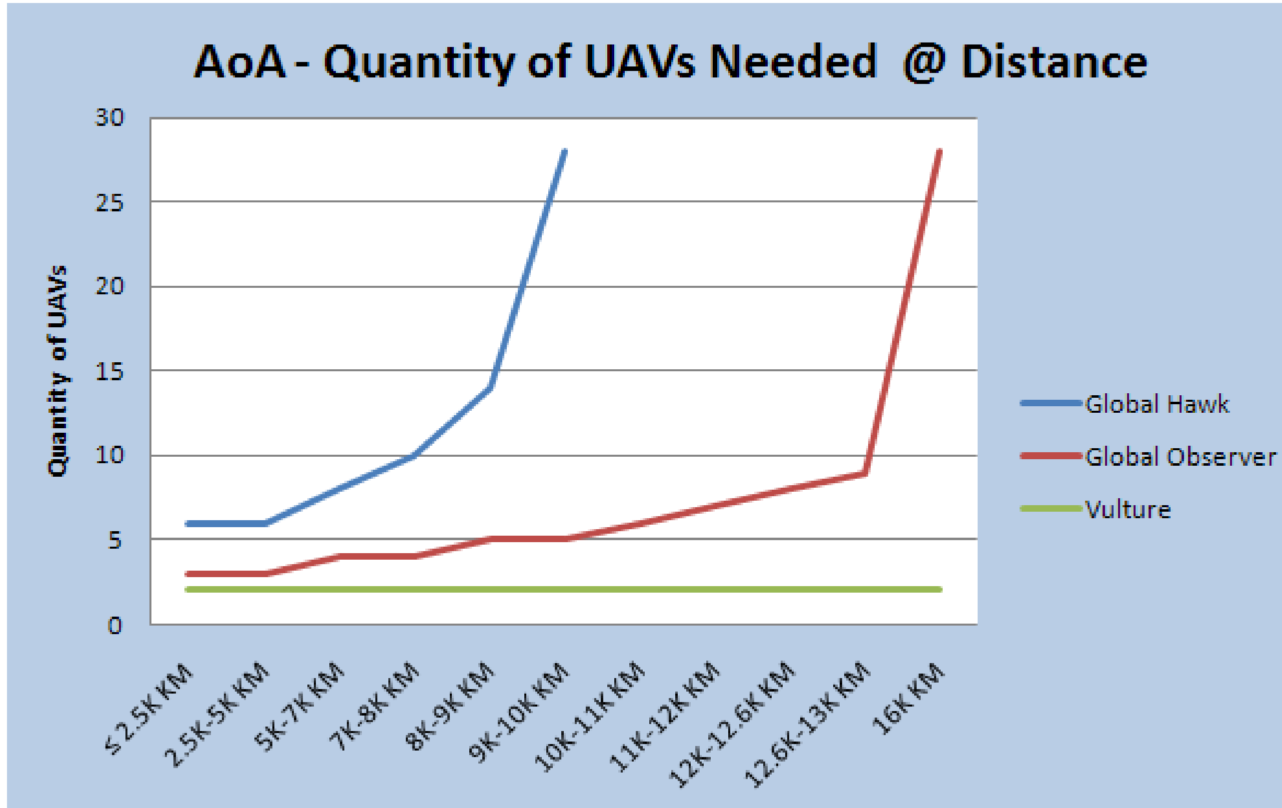
Vulture UAV Advanced Technology Cost Modeling

Analysis of Alternatives

- **Modeling of technical design baseline in TruePlanning against Global Hawk and Global Observer for seven years of Operation**
- **For each mission scenario (distance), calculate the number of aircraft needed to complete the mission.**
  - Example:
    - 5-7K km distance requires 8 Global Hawk or 4 Global Observer or 1 Vulture
    - 16K km distance requires 14 Global Hawk or 5 Global Observer or 1 Vulture

Set Up of the Alternatives for the HALE UAV





Quantiy of Aircraft @ Distance Threshold	≤ 2.5K KM	2.5K-5K KM	5K-7K KM	7K-8K KM	8K-9K KM	9K-10K KM	10K-11K KM	11K-12K KM	12K-12.6K KM	12.6K-13K KM	16K KM
Global Hawk	6	6	8	10	14	28					
Global Observer	3	3	4	4	5	5	6	7	8	9	28
Vulture	2	2	2	2	2	2	2	2	2	2	2

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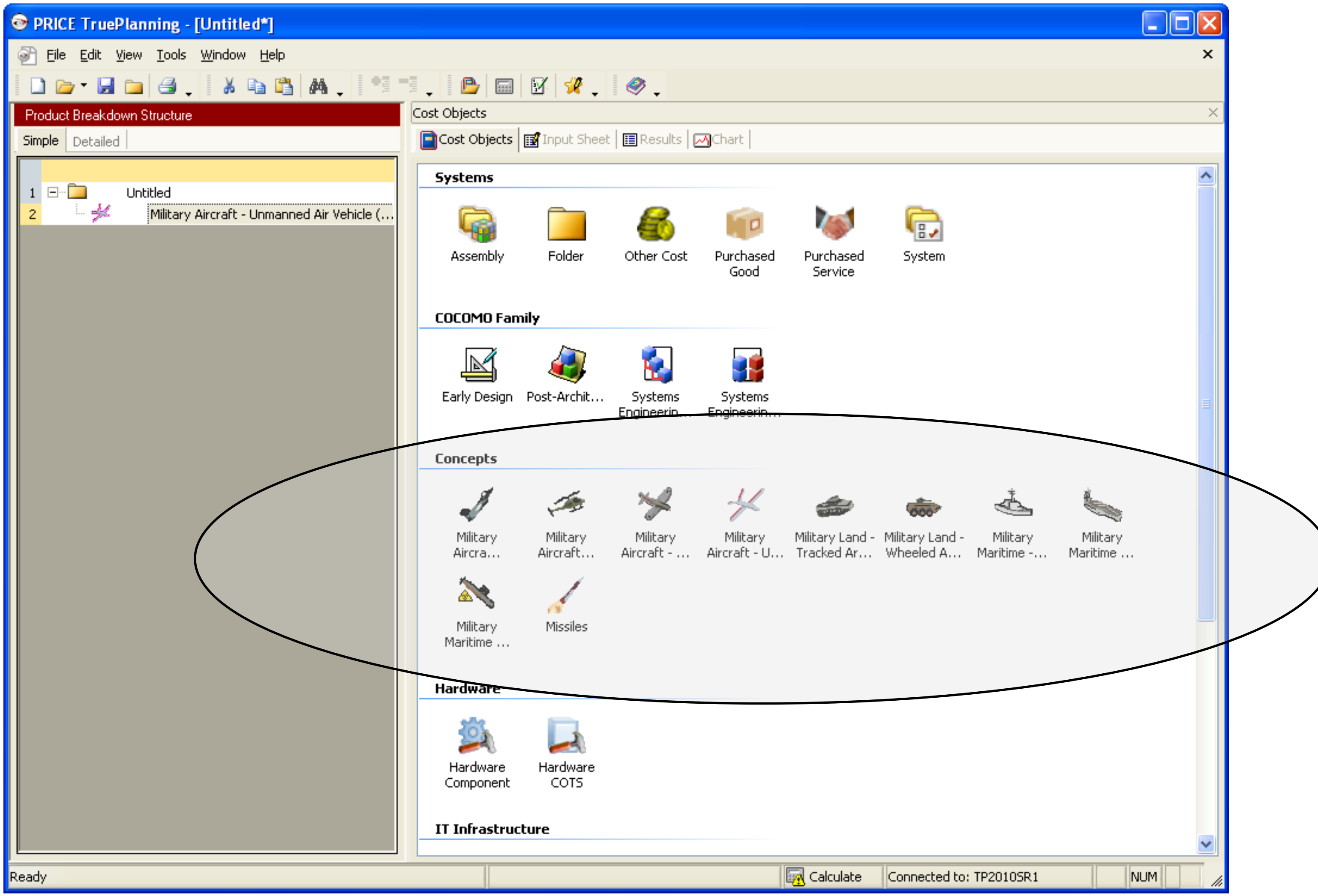
Conceptual Estimating Methodology

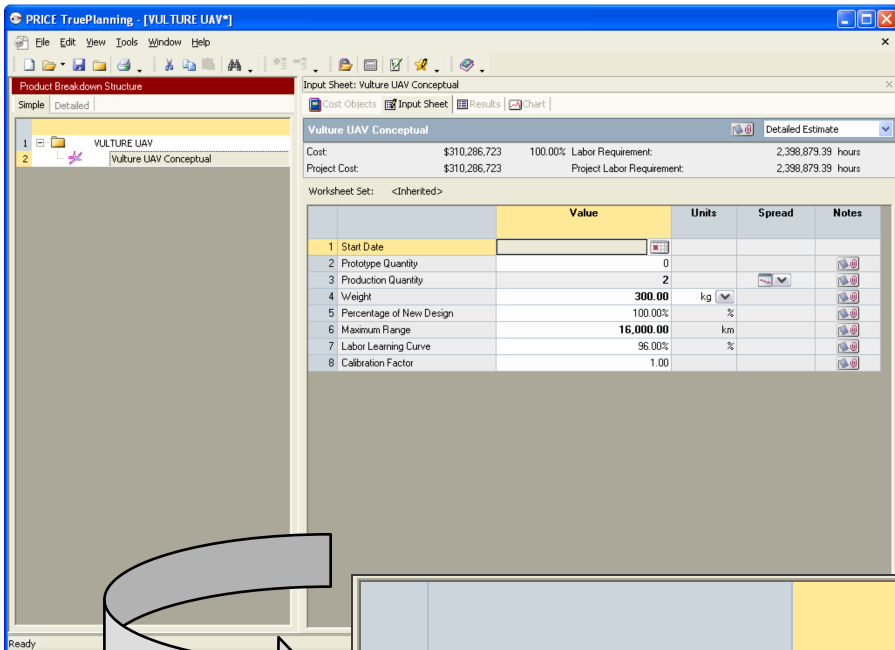
Vulture UAV - Airframe

- **For this exercise, we will be estimating advanced technology Vulture HALE UAV using a conceptual parametric model since little data is known.**
- **TruePlanning for Concepts models were built in partnership between PRICE Systems and the United Kingdom (UK) Ministry of Defence (MOD) Defence Equipment and Support (DE&S) organisation.**
- **Currently ten Cost Objects exist with the ability to predict parametrically the cost and schedule of specific Systems using high level cost drivers deemed to be available during pre-concept and concept phases of a project life cycle**

TruePlanning for Concepts – UAV Estimating



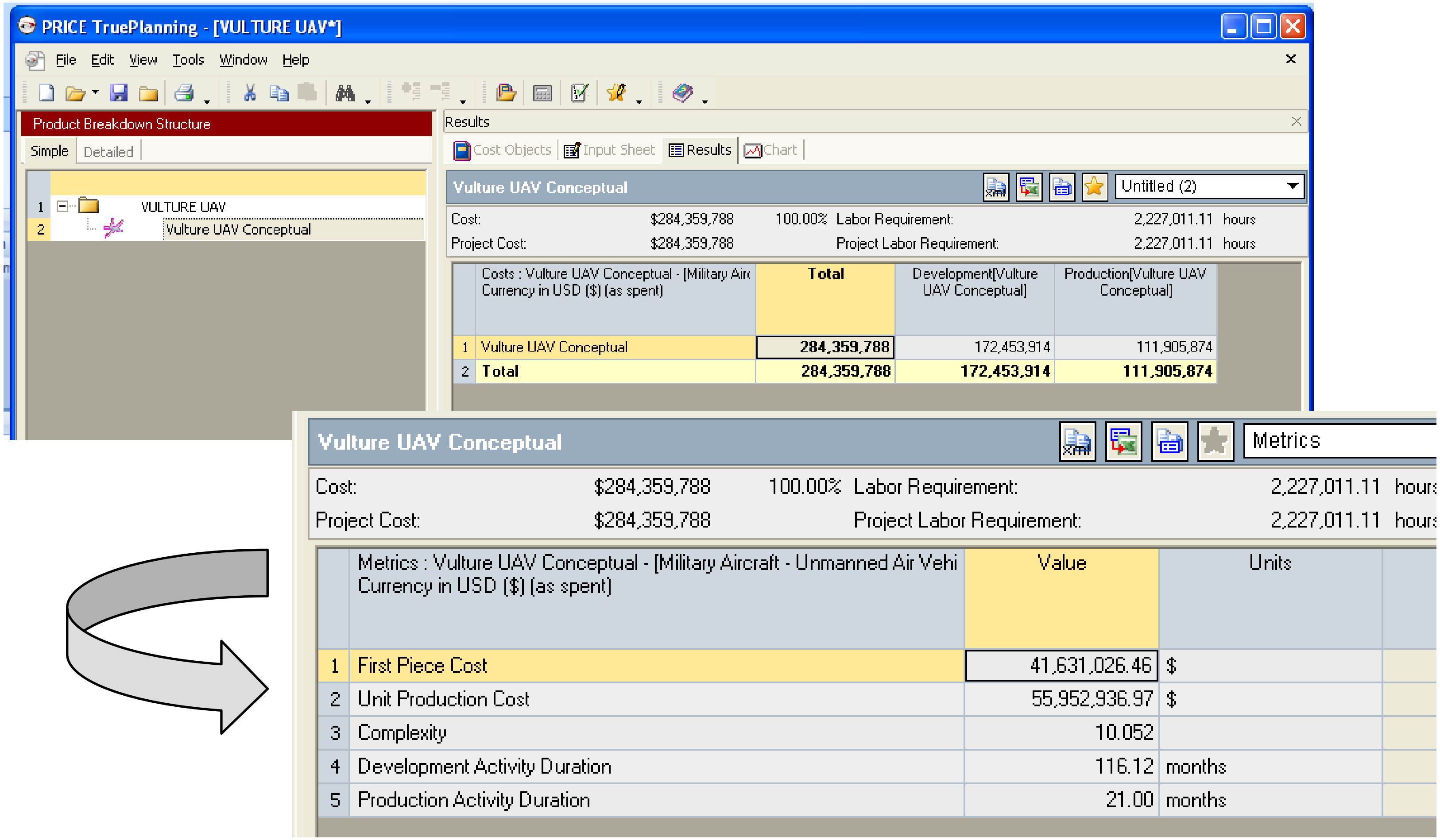
TruePlanning for Concepts
HALE UAV - Vulture



		Value	Units	Spread	Notes
1	Start Date				
2	Prototype Quantity	0			
3	Production Quantity	2			
4	Weight	300.00	kg		
5	Percentage of New Design	90.00%	%		
6	Maximum Range	16,000.00	km		
7	Labor Learning Curve	96.00%	%		
8	Calibration Factor	1.00			

Minimum Inputs:
- Quantity = 2
- Weight = 300kg
- % New Design = 90%
- Maximum Range = 16,000km

TruePlanning for Concepts
Vulture HALE UAV Estimate/Metrics



Generated complexity Value of 10.0 can be used to generate life cycle cost estimates

Custom CER Cost Estimating Methodology

Vulture UAV - Airframe

- **The TruePlanning 2010 SR1 parametric model has the capability of creating custom CERs based on your own specific cost history.**
- **Some of the benefits of this approach are having both your own custom CERs and data integrated into the TruePlanning framework for additional analysis allowing side-by-side comparison with other PRICE methodologies.**
- **Using TrueAnalyst, this data can be used to develop custom data-driven cost objects using the cost/performance parameters directly from an your own data, for example an EXCEL file.**

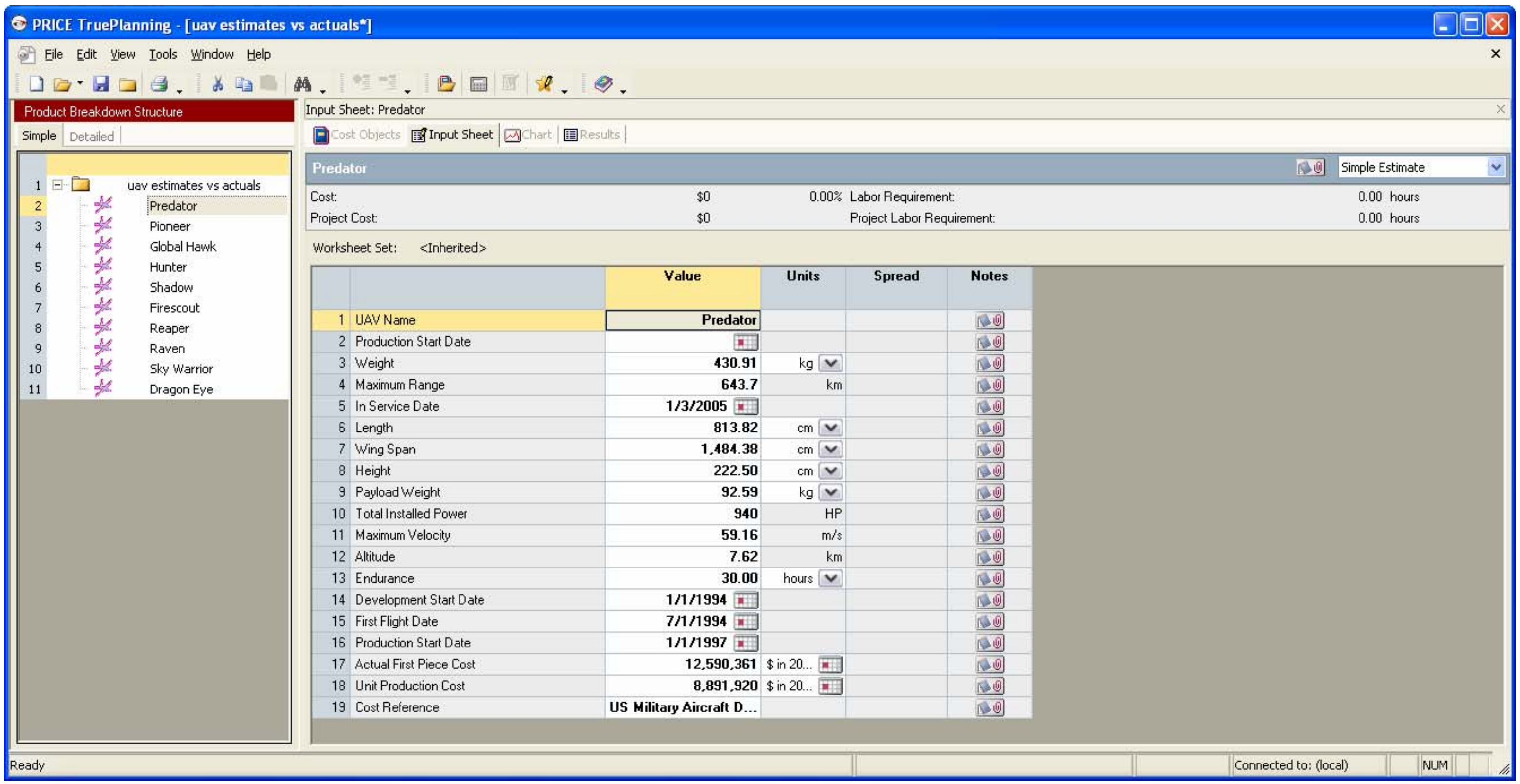
Custom CER Cost Estimating – UAV Cost/Performance Data

UAV Name	Start Date	Weight (kg)	Maximum Range (km)	In Service Date	Length (cm)	Wing Span (cm)	Height (cm)	Payload Weight (kg)	Total Installed Power (hp)	Maximum Velocity (m/s)	Altitude (km)	Endurance (hrs)	Development Start Date	First Flight Date	Production Start Date	Actual First Piece Cost (2006)	Unit Production Cost (2006)
Predator	1/1/1997	430.91	643.7	2005	813.82	1484.38	222.50	92.59	940	59.16	7.62	30.00	1/1/1994	7/1/1994	1/1/1997	$12,590,361	$8,891,920
Pioneer	12/1/1985	137.89	160.9	1986	426.72	518.16	100.58	15.43	26	56.59	4.57	5.00		10/1/1985	12/1/1985	$4,560,064	$3,425,079
Global Hawk	6/1/2001	4,173.05	21,726.1	2006	1353.31	3541.78	445.01	401.20	7,600	180.05	19.81	32.00	10/1/1994	2/1/1998	6/1/2001	$129,752,740	$102,586,327
Hunter	6/1/1992	544.31	231.7	1995	701.04	890.02	164.59	41.15	136	54.53	4.57	12.00	10/1/1988	9/1/1990	6/1/1992	$16,396,907	$12,936,140
Shadow	12/1/1999	136.08	173.8	2002	341.38	390.14	27.43	12.34	38	63.28	4.57	5.00	3/1/1999	6/1/2000	12/1/1999	$7,479,516	$5,329,147
Firescout	6/1/2006	830.53	241.4	2008	697.99		286.51	123.45	420	64.31	6.10	6.00	2/1/2000	1/1/2000	6/1/2006	$11,572,404	$8,557,895
Reaper	6/1/2008	1,678.29	2,663.5	2009	1097.28	2011.68	381.00	771.55	900	115.75	15.24	30.00	6/1/2008		6/1/2008	$21,810,874	$17,302,464
Raven	6/1/2003	1.91	9.7	2003	91.44	137.16				22.64	4.57	1.00		10/1/2001	6/1/2003	$92,551	$56,774
Sky Warrior	6/1/2006	430.91	643.7	2010	853.44	1706.88	222.50	221.18	135	77.17	8.84	30.00	12/1/2003	6/1/2006	6/1/2006	$14,085,625	$10,691,048
Dragon Eye	12/1/2003	1.36	9.7	2004	73.15	115.82	9.14			18.01	0.15	1.00	2/1/2000	5/1/2000	12/1/2003	$102,717	$66,065

UAV Historical Data from US Military Aircraft Data Book 2008 Thirtieth Edition section 5

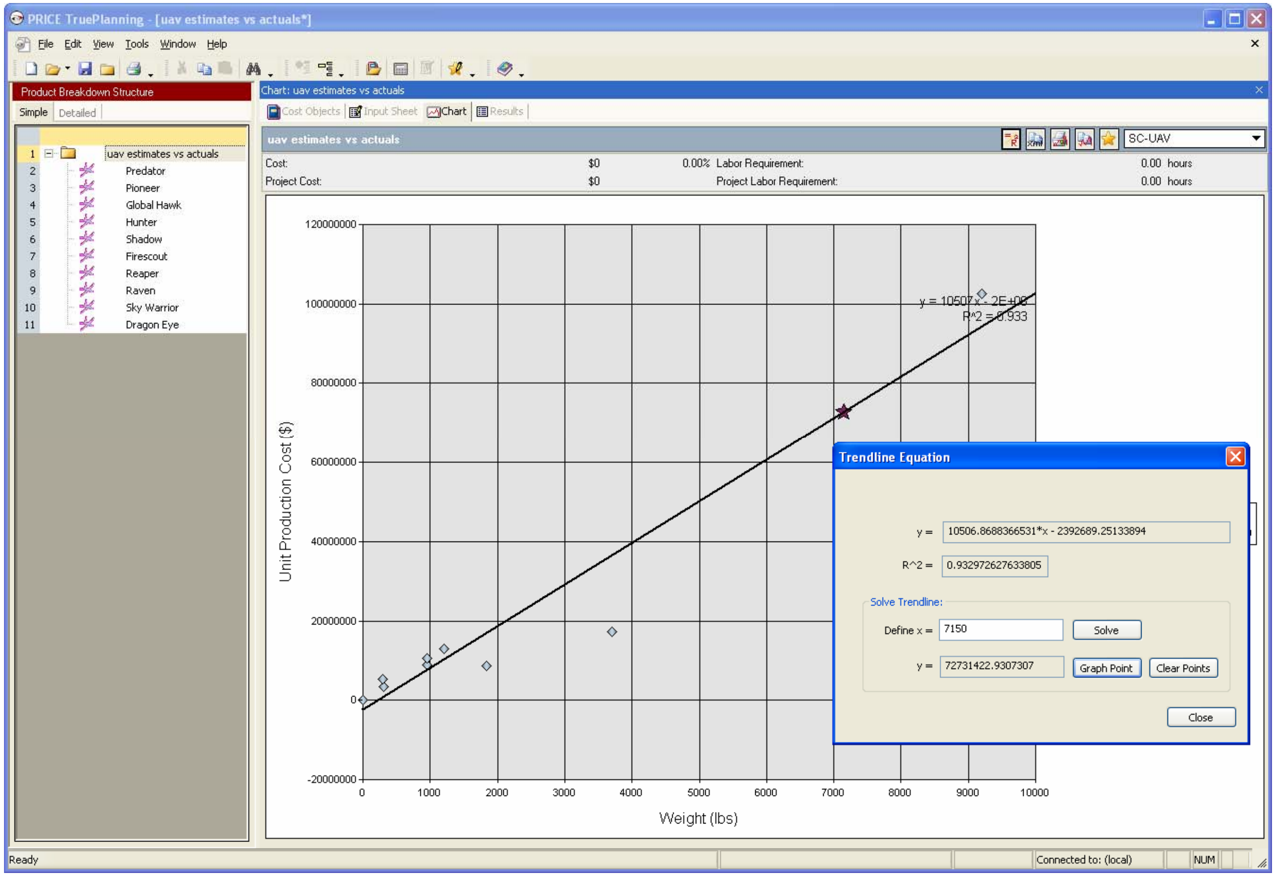
Custom CER Cost Estimating – UAV Cost/Performance Data in TruePlanning

The ten historical UAV points along with their cost/performance data can now be built into custom cost objects within TruePlanning.



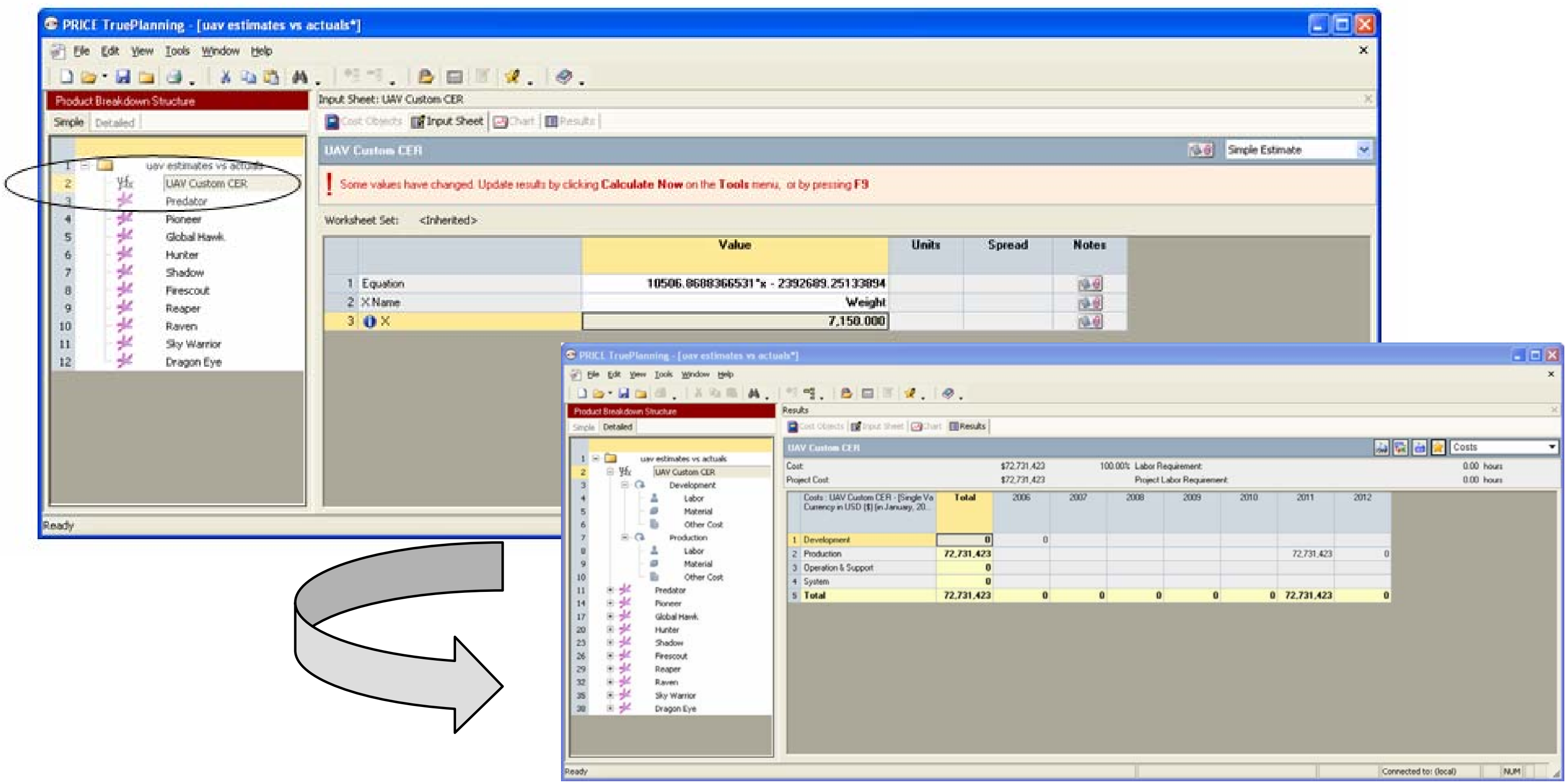
Custom CER Cost Estimating – UAV Data-Driven Trendline in TruePlanning

Results of our historical UAV scatter plot analysis including the trend line for weight vs. unit production cost. Note R^2 is displayed along with the ability to "solve" for any defined weight.



Custom CER Cost Estimating – UAV Data-Driven Trendline in TruePlanning

Once we have developed the trendline equation, we can now develop a custom CER cost object in TruePlanning by simply copying the equation into a single variable equation cost object and defining the X variable as



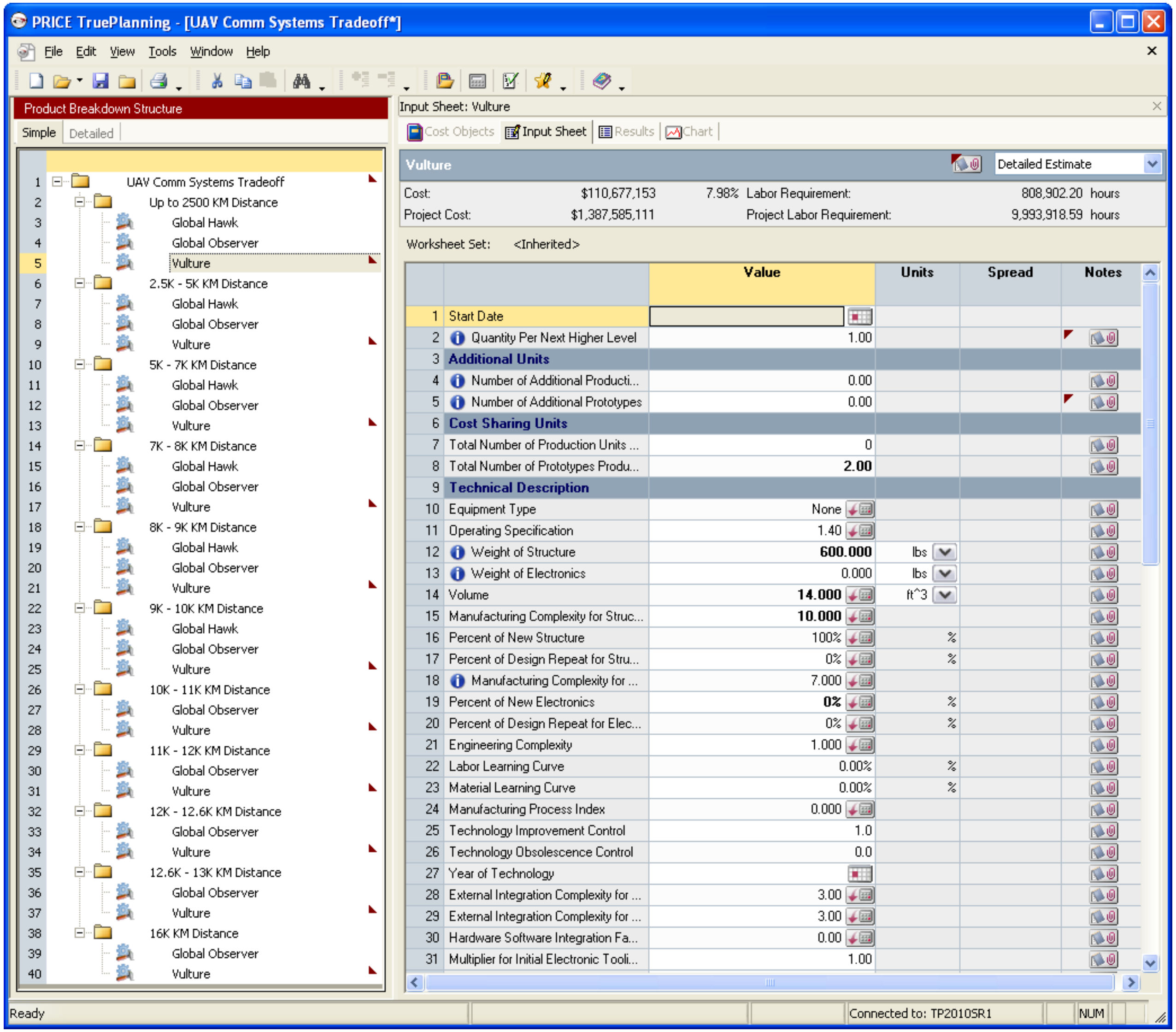
Populating the Vulture AoA

TruePlanning for Hardware

- Now that we have estimated Vulture HALE UAV in TruePlanning Concepts model (or through your own data-driven CERs) and generated a complexity value or CER custom equation, we can now include it in TruePlanning for Hardware model along with Global Hawk and Global Observer to produce full lifecycle cost estimates.
- At this point it's possible to refine the estimate further and consider breaking the hardware elements down into sub-systems or equipments as the definition of the systems becomes more detailed.
- As the project life passes the appropriate estimating methodology is used with the appropriate project phase.

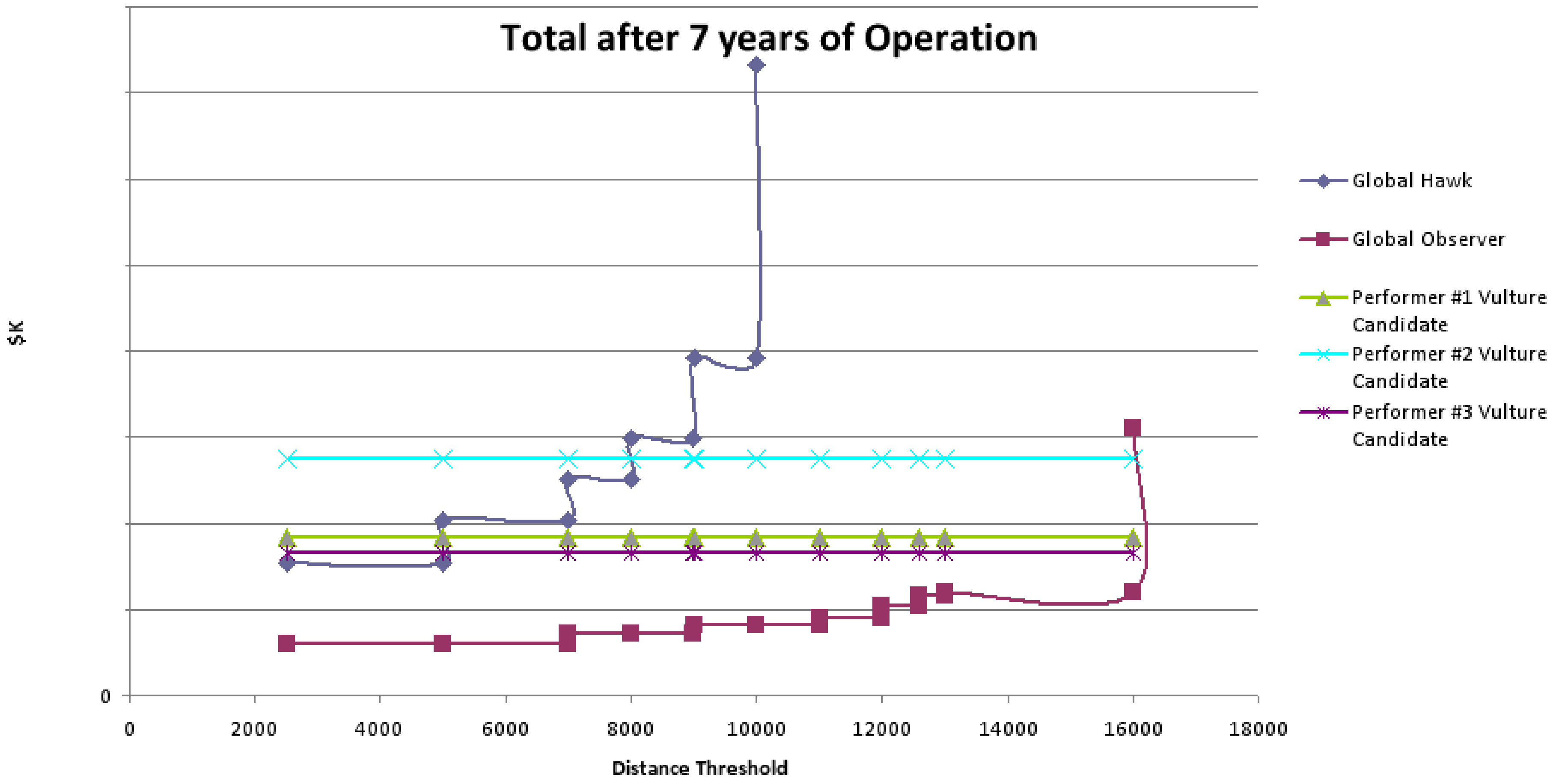
Populating the Vulture AoA

TruePlanning for Hardware



- Global Hawk and Global Observer were calibrated based on actual data in the public domain.
- Vulture based on modelling in TrueConcepts to obtain the complexity value.

HALE UAV AoA Results



HALE UAV AoA Observations

- **Greater distance thresholds favor Vulture UAV over Global Hawk and Global Observer**
- **Global Hawk is not really a viable option past 10k km.**
- **Concepts of operation and maintaining are critical – the greater the operational intensity, the greater the advantage seems to be for Vulture.**
- **AoA demonstrates that while Vulture HALE UAV is higher cost Operational for shorter mission, it is more cost effective for the 16k km missions**

Conclusions

- **Analysis of Alternatives (AoA) is a key tool for early estimating of Advanced Technology Programs.**
- **However, the AoA must take into account not only performance, but the entire Lifecycle cost impact.**
- **Advanced Technology Program estimating may be difficult when no comparable technology exists.**
  - ATP estimates should be “triangulated” by using several cost estimating techniques (parametric, SME, bottoms-up)
- **The AoA when coupled with systems’ engineering analysis is a key tool in evaluating new technology development against competing current alternatives.**