Cost Analysis & Assurance Service

Weapons Integration Cost Modelling
Presentation to SCAF

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WIUK Challenge

For any future weapons or aircraft programme, significantly reduce the cost, and time taken for systems integration.

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Weapons Integration Background

Background

- Integration costs & timescales significant for Aircraft/Weapons Systems.
- A barrier to acquiring new capabilities.
- UK MOD funded, via the RAO, the Weapons Integration UK study to:
  - Identify & quantify non recurring integration cost & timescale drivers.
  - Identify opportunities for reducing costs & improving timescales.
  - Establish a means of estimating integration costs.
  - Enable targets to be set for improvement opportunities.
- Key industry stakeholders formed the WIST team to take part in the WIUK study.
- CAAS involved in 2010
  - Determine an appropriate CER based on actual data.
  - Establish a method of allocating cost to drivers
  - Enable improvement targets to be set.

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Key Industry Participants

AgustaWestland

BAE SYSTEMS

MBDA MISSILE SYSTEMS

QinetiQ

Raytheon UK

THALES

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Analysis Activities

- Gather historic data
  - Industry - Contract Information (Actual Cost/Price breakdowns)
  - DE&S PTs - Other Costs - (Cost/Price breakdowns).
- Analyse data (via workshops)
  - Consolidated view of non recurring engineering cost drivers
  - Normalised data (Escalation rate, Common Currency, etc)
  - Identified appropriate complexity levels (Platform/Weapon/Environment)
  - Allocated cost to cost driver (SME input) Quantified % split of cost across each driver (Min, Avge, Max)
  - Regression analysis (Derive appropriate relationship)
  - Quantified uncertainty levels
  - Test relationship (hypothesis testing, etc)

Data Points

Platform	Weapon System	Complexity Level			
		Platform	Weapon	Environment	Average
Harrier	Paveway IV	1	1	1	1
Harrier	Brimstone	1	2	1	1.3
Wildcat	FASGW(H)	1	2	1	1.3
Wildcat	FASGW(L)	1	4	1	2
Tornado	Brimstone	2	2	2	2
Tornado	Stormshadow	2	2	2	2
Tornado	ASRAAM	2	2	2	2
Tornado	AMRAAM	2	4	2	2.7
Typhoon	Paveway IV	4	1	4	3
Typhoon	ASRAAM	4	2	4	3.3
Typhoon	Stormshadow	4	2	4	3.3
Typhoon	SPEAR C2	4	4	4	3.3
Typhoon	Meteor	4	4	4	4
Lightning (JCA)	Paveway IV	4	1	4	3
Lightning (JCA)	Meteor	4	4	4	4

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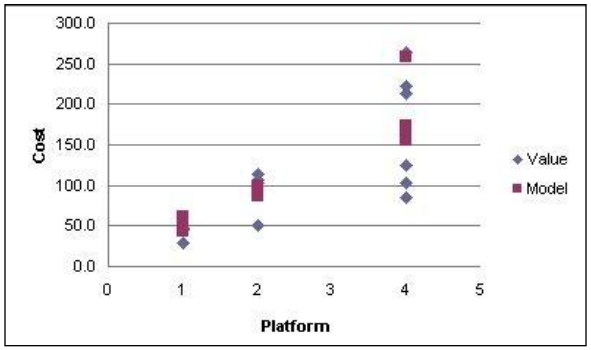
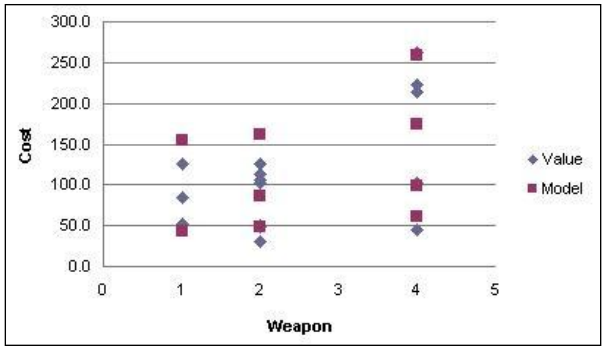
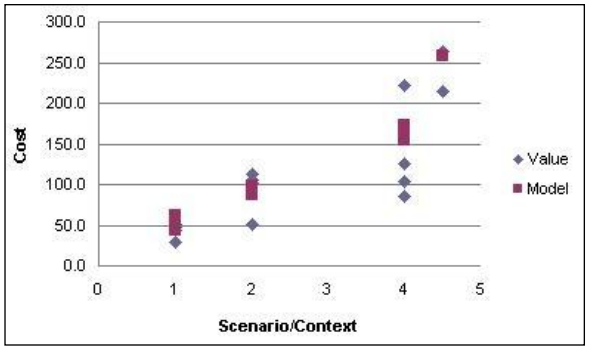
Selection of Independent Variable - Complexity

3 complexity variables to consider.







Combination

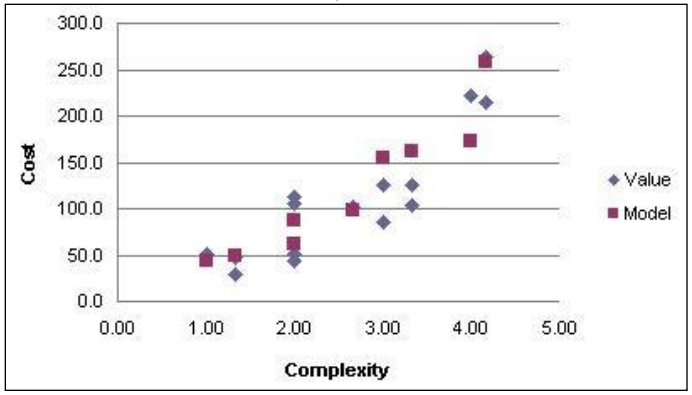
Assessed each individual complexity as cost driver.

Statistical assessment demonstrated:

Too many parameters

Parameters highly correlated

Poor regression relationships



Hence:
Combination of all three via average selected.
Better fit

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Cost Breakdown

Work Breakdown Structure	Min %	Av %	Max %
A - Wpn Sys Integration Requirements	1%	5%	18%
B - Functional Definition & development	7%	11%	27%
C - Interface Definition	4%	8%	12%
D - Aero Mechanical	4%	8%	12%
E - Weapon Carriage Trials	3%	11%	15%
F - EMC	2%	4%	5%
G - Separation	7%	14%	26%
H - System Safety	5%	11%	14%
I - Functional Validation	11%	20%	30%
J - Airworthiness/Certification	0.4%	4%	6%
K - Weapon System Evaluation	1%	3%	14%

Established the degree of correlation between the various elements using SME judgement

From WIST Report 2007.

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Regression Analysis

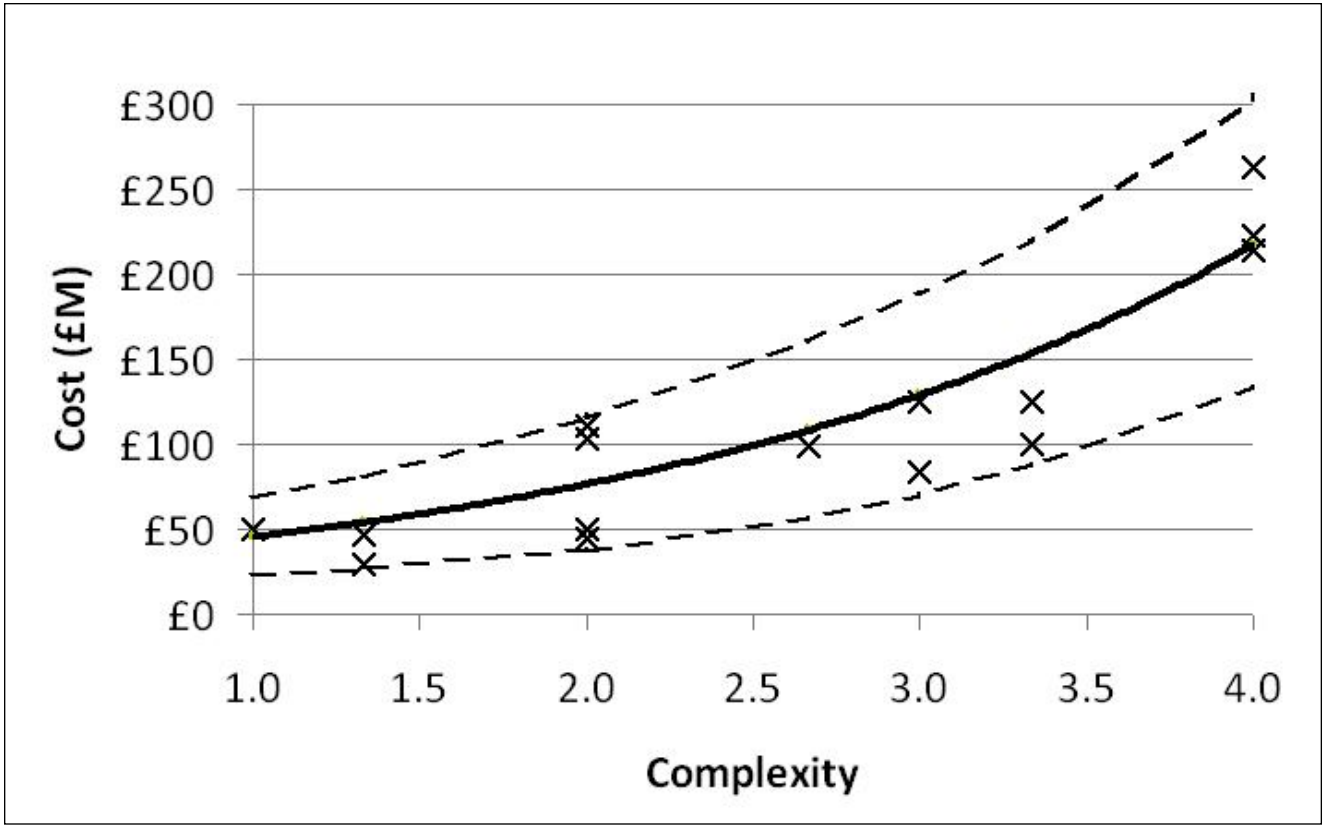
Reality Check:

CER estimate within 10% of independent estimate based on alternative method (latest Meteor on Typhoon estimate).

Uncertainty:

Residual Value Analysis to address measurement noise.

Principle is to ensure that Value of differences between theoretical & actual is minimised (→ 0)



Result:

Evidence based CER for estimating baseline integration costs given a set of expert judgemental complexity assessments.

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Quantifying Uncertainty

- Needed to ensure that, on average, the level of theoretical uncertainty matched the actual uncertainty

  Average actual differences = average theoretical differences
- Used Excel goal seek to establish a constant factor covering measurement noise
- Used this factor to quantify the uncertainty to apply as an adjusted CER for the upper & lower bounds.

Application of Model - Estimating benefits

- Plug & Play (standard connections, interfaces & mountings with parameter driven stores management)
  - Impact on cost drivers
- Re-use of Data (Platform/Weapon)
  - Impact on cost drivers
- Used to forecast benefits & costs for integration improvement initiatives based on a % saving from baseline

Weapons Integration Cost Modelling

Integration Cost Model

What is the complexity of:

		Complexity Score
Platform	High	4
Weapon	High	4
Scenario/context	High	4
Average Complexity Score =	4.0	

What elements are to be included in the estimate?

A - Wpn Sys Integration Requirements	Yes
B - Functional Definition & development	Yes
C - Interface Definition	Yes
D - Aero Mechanical	Yes
E - Weapon Carriage Trials	Yes
F - EMC	Yes
G - Separation	Yes
H - System Safety	Yes
I - Functional Validation	Yes
J - Airworthiness/Certification	Yes
K - Weapon System Evaluation	Yes

Level of efficiency saving (%) from base line for each element.

A - Wpn Sys Integration Requirements	10%
B - Functional Definition & development	0%
C - Interface Definition	10%
D - Aero Mechanical	10%
E - Weapon Carriage Trials	0%
F - EMC	20%
G - Separation	0%
H - System Safety	15%
I - Functional Validation	0%
J - Airworthiness/Certification	25%
K - Weapon System Evaluation	10%

Notes

- Example: Photon Torpedo on Thunderbird 1.
- Parameters entered:
  - Platform complexity High (Supersonic VSTOL Platform)
  - Weapons Complexity High (Energy Weapon)
  - Scenario/Context complexity High (Multi-national procurement)
- All WBS estimates required
- Impact of efficiency savings within WBS Estimates entered as parameters.
- Uses Statistical Simulation techniques to determine confidence limits (Palisade @Risk) for results.

Example: Less Software development reduces functional definition & development costs & also implies less functional validation; hence reduced functional validation costs.

Input parameters are for illustrative purposes only and do not refer to any existing or future MOD programme or project.

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Estimate Values

SHOULD COST

Baseline – No account of improvements

BASELINE ESTIMATE WITH ALL WBS ELEMENTS

Total 10-50-90	10	50	90	Deterministic
	183.54	213.88	244.27	201.22

WBS 10-50-90 Profiled for presentation	10	50	90	Deterministic
A - Wpn Sys Integration Requirements	4.17	10.27	19.90	6.70
B - Functional Definition & development	16.48	23.49	34.93	18.52
C - Interface Definition	13.25	18.39	22.91	18.53
D - Aero Mechanical	11.74	16.55	21.78	15.92
E - Weapon Carriage Trials	16.78	24.51	30.92	25.92
F - EMC	6.23	8.23	9.91	8.40
G - Separation	19.41	29.45	40.45	26.92
H - System Safety	16.85	23.58	29.27	24.47
I - Functional Validation	32.13	44.08	55.07	43.11
J - Airworthiness/Certification	5.55	8.85	11.43	9.54
K - Weapon System Evaluation	2.71	6.48	13.39	3.20

BASELINE ESTIMATE WITH SELECTED WBS ELEMENTS

10	50	90	Deterministic
177.54	213.35	252.53	201.22

10	50	90	Deterministic
4.17	10.25	19.90	6.70
16.48	23.43	34.93	18.52
13.25	18.34	22.91	18.53
11.74	16.51	21.78	15.92
16.78	24.45	30.92	25.92
6.23	8.21	9.91	8.40
19.41	29.37	40.45	26.92
16.85	23.52	29.27	24.47
32.13	43.97	55.07	43.11
5.55	8.83	11.43	9.54
2.71	6.47	13.39	3.20

Forecast – Including prospective improvements

COULD COST

Forecast Cost after savings made

WITH WIUK EFFICIENCIES APPLIED

Total 10-50-90	10	50	90	Deterministic
	166.82	200.79	237.79	189.05

WBS 10-50-90 Profiled for presentation	10	50	90	Deterministic
A - Wpn Sys Integration Requirements	3.75	9.22	17.91	6.03
B - Functional Definition & development	16.48	23.43	34.93	18.52
C - Interface Definition	11.92	16.50	20.62	16.68
D - Aero Mechanical	10.57	14.86	19.60	14.33
E - Weapon Carriage Trials	16.78	24.45	30.92	25.92
F - EMC	4.99	6.57	7.93	6.72
G - Separation	19.41	29.37	40.45	26.92
H - System Safety	14.33	19.99	24.88	20.80
I - Functional Validation	32.13	43.97	55.07	43.11
J - Airworthiness/Certification	4.16	6.62	8.57	7.15
K - Weapon System Evaluation	2.44	5.82	12.05	2.88

Forecast savings

BENEFIT OF WIUK EFFICIENCIES

10	50	90	Deterministic
10.72	12.56	14.73	12.17

10	50	90	Deterministic
0.42	1.03	1.99	0.67
0.00	0.00	0.00	0.00
1.32	1.84	2.29	1.85
1.17	1.65	2.18	1.59
0.00	0.00	0.00	0.00
1.25	1.64	1.98	1.68
0.00	0.00	0.00	0.00
2.53	3.53	4.39	3.67
0.00	0.01	0.00	0.00
1.39	2.21	2.86	2.38
0.27	0.65	1.34	0.32

Output results from model are based illustrative input parameters in previous slide and do not refer to any existing or future MOD programme or project

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Weapons Integration Cost Modelling

Summary

- Gathered & Validated data from various sources.
- Derived an understanding of the non recurring engineering cost drivers.
- Developed a Cost Breakdown structure.
- Established a statistically robust ‘baseline’ cost estimating relationship:
  - Complexity (Platform/Weapons/Procurement) vs Cost
  - Understanding of the level of uncertainty.
  - Including the degree of correlation between the individual drivers (CBS).
- Developed a parametric model that:
  - Predicts costs given an outline understanding of the complexity of the integration activity.
  - Incorporates uncertainty to generate a ‘three point’ estimate.
  - Enables cost to be split across the individual drivers.
  - Forecasts the potential impact of improvements on integration costs.

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Weapons Integration Cost Modelling

Next Steps

- Implementation
  - Document the model & any constraints on its use.
  - CAAS to formally assure the model
  - Maintenance of model.
- Further definition of ‘could cost’ estimating/approach.
- Application to forecasting wider DLOD integration costs.
- Application of modelling approach to:
  - Weapons on other platforms/sectors.
  - Other systems integrations.
  - Schedule estimates.

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Acknowledgements

Graham Morrison

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? Questions ?

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