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Society for Cost Analysis and Forecasting

A novel emergent System Dynamics approach to through life cost estimation

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QinetiQ

8th February 2018

Introductions

Peter Tart

- Operational Analyst with 20 years experience primarily within Defence.
- Specialises in Balance of Investment, options assessment and cost capability trade methods.
- Led the US DoD's Operating and Support Cost Analysis Model (OSCAM) development and training team.

Colin Sandall

- Operational Analyst with over 25 years experience in Defence.
- Specialises in cost-benefit and cost-effectiveness analysis.
- Was the lead software engineer and trainer for OSCAM.

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MOD cost estimating issues raised

- “The Department does not yet fully understand its equipment support costs… support costs are a complex and highly variable set of cost lines that the Department understands less well than it does the procurement costs” Public Accounts Committee, May 2014
- “MOD frequently has no clear understanding of the link between support costs (i.e., inputs) and the military outputs” (e.g., flying hours achieved). Review of Acquisition for the Secretary of State for Defence, Bernard Gray, October 2009
- “Current arrangements incentivise the under-estimation of support costs rather than the generation of accurate estimates… The second undesirable feature of the current system that is routinely criticised is the fundamental inability of the acquisition community to provide adequate cost estimates at the outset of a project… Sophisticated financial modelling tools would allow teams to make trades between initial acquisition, maintenance, training, and infrastructure costs of different possible systems.” Review of Acquisition for the Secretary of State for Defence, Bernard Gray, October 2009
- “The impact of risk covariance (i.e. correlation) may also be underestimated. Thus, when each activity is considered in isolation, it is easy to underestimate the real variance that could occur… Not taking due account of dependent variables is one of the main reasons why analysis using Three-Point Estimates fails to describe the complete range of possible outcomes.” Three Point Estimates and Quantitative Risk Analysis a Process Guide for Risk Practitioners, CAAS

Limitations of classic cost estimating techniques

Requirement
Robust, standardised, accurate and repeatable whole life equipment support forecasting.
Directly links cost to programme output.
Ability to compare equipment support costed options.
A flexible capability that can model all types of equipment support budget forecasts.
Aligns to cost estimating guidance, especially in the area of uncertainty correlation.

Conclusion

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Classic approach to Systems Dynamics

- Systems Dynamics is a powerful mechanism for understanding interactions, secondary and tertiary effects, and time delays.
- SD provides feedback loops – higher demand in one time step can result in lower achievement later due to effects on equipment availability.
- SD models inform when costs fall as well as what their value is.

However,

- SD is not a simulation and does not track individual entities giving rise to ‘averaged’ estimates;
- SD based models are difficult to adapt and expand;
- SD models are difficult to create in Excel.

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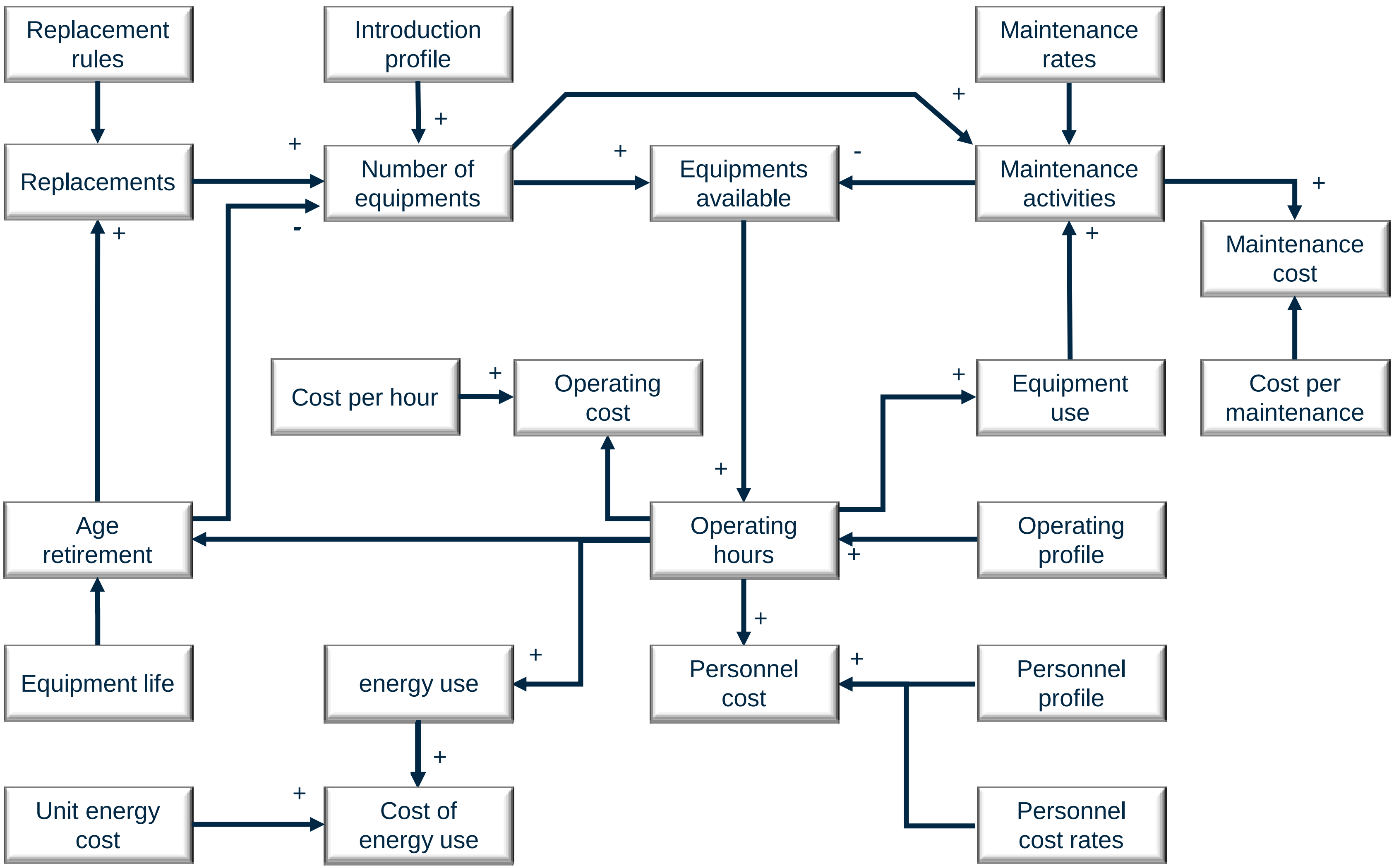
Classic approach to Systems Dynamics



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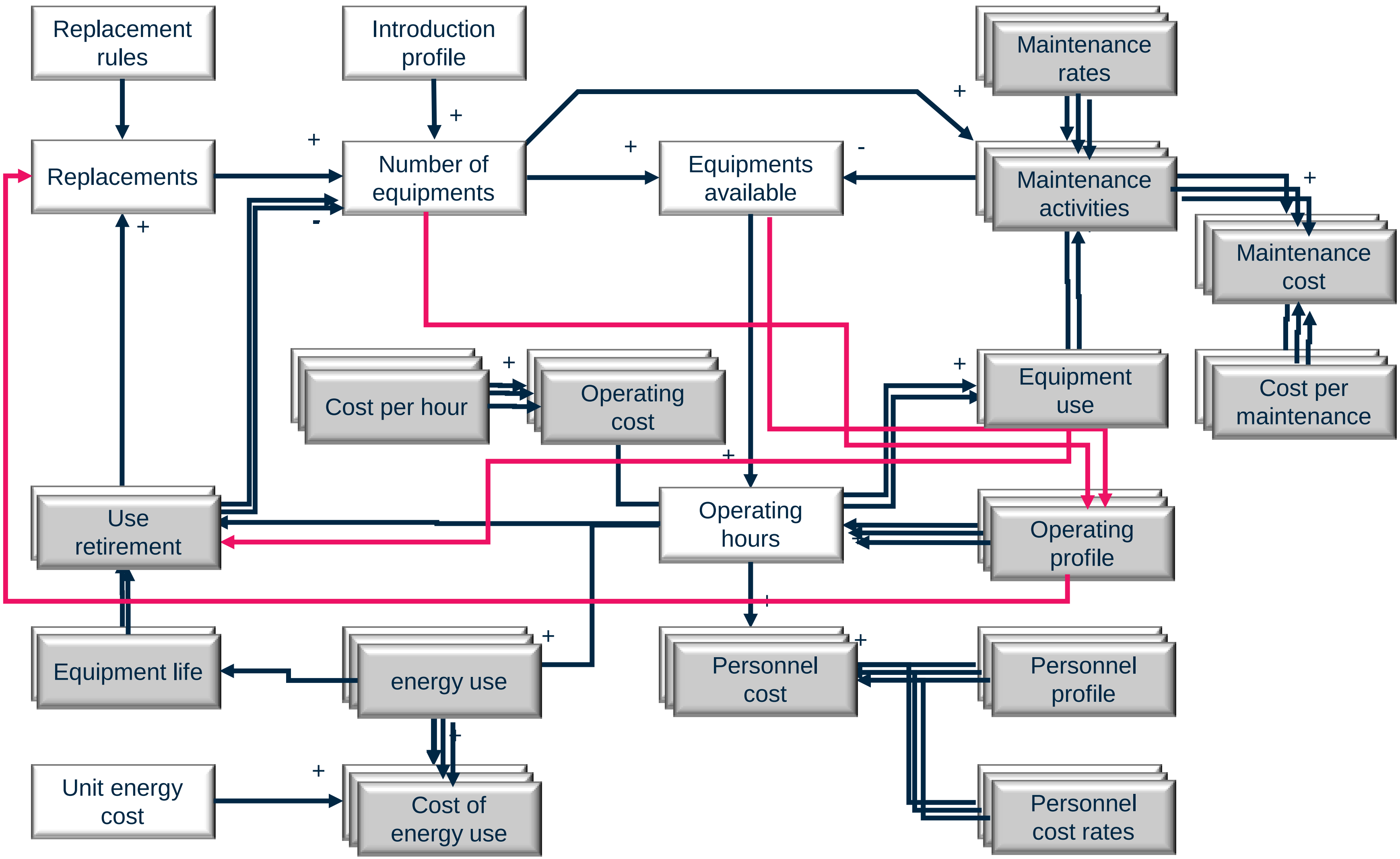
Classic approach to Systems Dynamics



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Classic approach to Systems Dynamics

- Classic System Dynamics models have an inflexible model structure and fixed data inputs.
- Changing a verified model to incorporate new elements or to update the interactions is difficult and time consuming.
- Each model is only applicable within one domain.
- SD is not entity based resulting in averaged activities.
- Risks and their consequences cannot be fully represented.

A new approach – Individual Entity Emergent System Dynamics

A new approach is required that has:

- the time based interactions and behaviours of System Dynamics;
- the incorporation of risk events and correlation to correctly represent uncertainty;
- entity based simulation components to better derive uncertainty;
- greater flexibility than existing modelling methods;
- greater efficiency than bespoke Excel modelling.

AFFORD is an IEESD cost simulation framework that provides:

- an Emergent SD model that is defined by the user from a set of standard components;
- a Monte-Carlo, individual-entity based simulation incorporating uncertainty and risks in the simulation;
- data management, including assumptions and revision history for all inputs;
- mechanisms to view, report and understand outputs, including user defined output taxonomies;
- the ability to generate and re-use cost estimate model templates.

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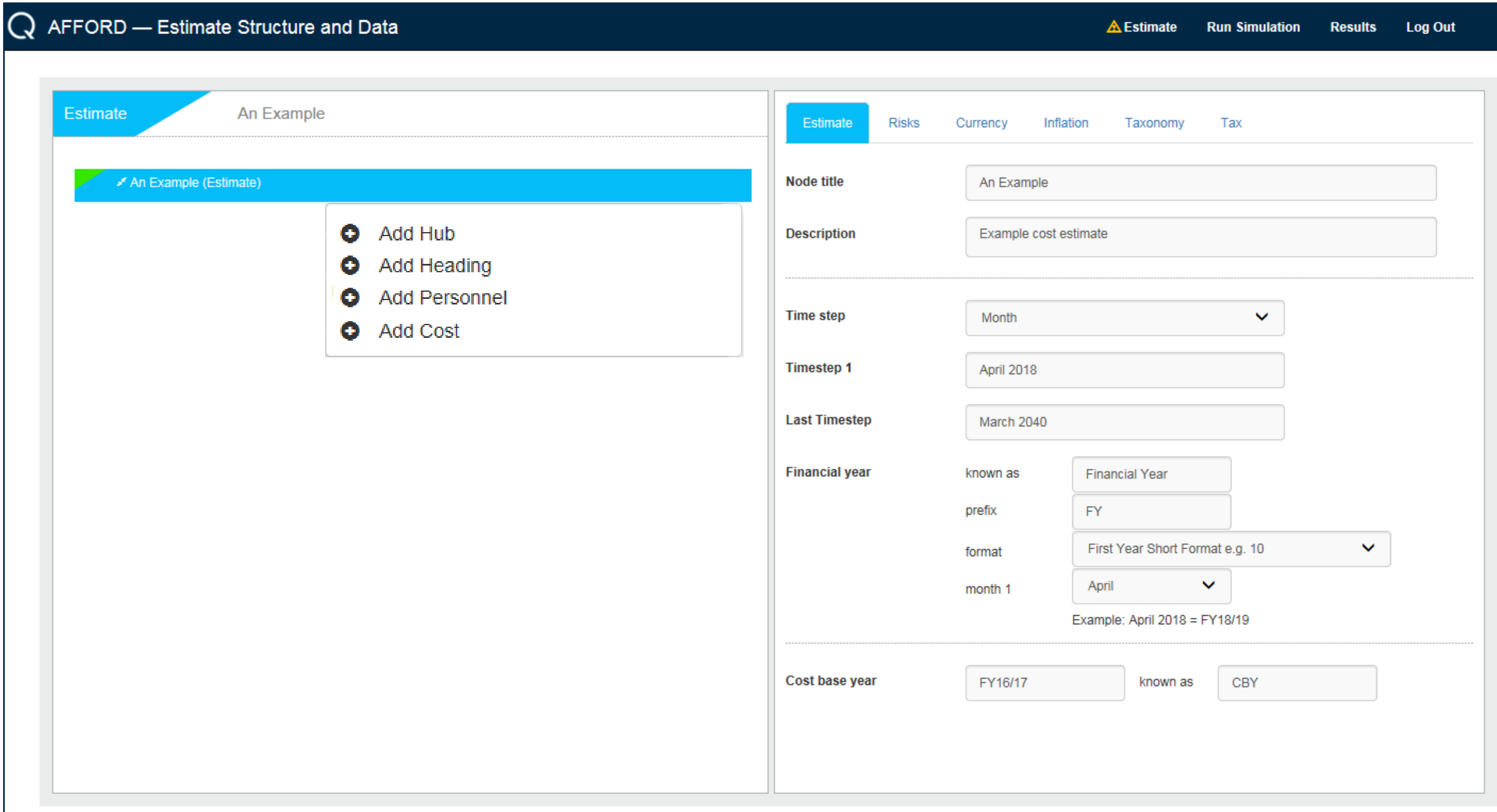
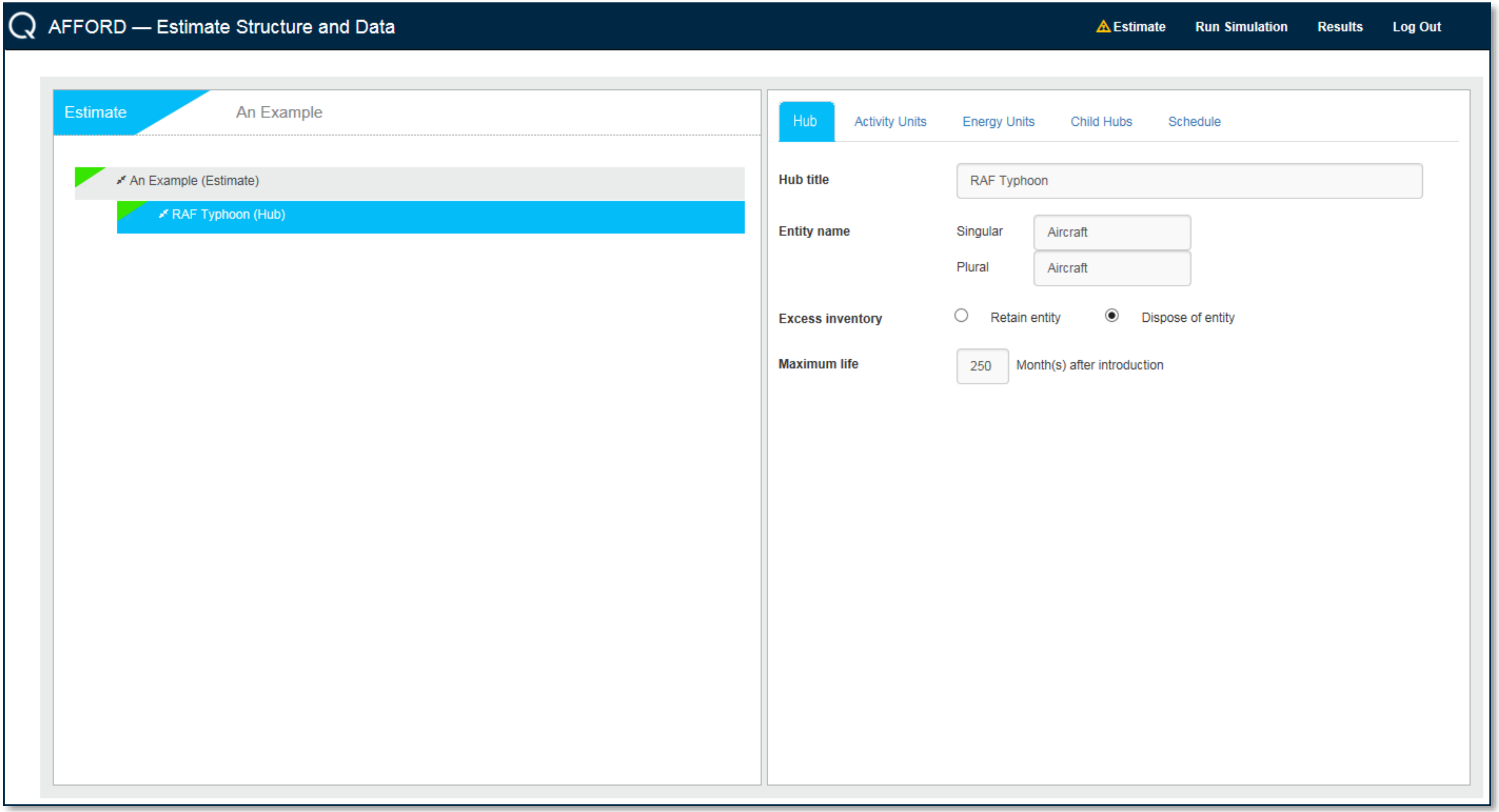
Worked example - Estimate



Worked example - Hub



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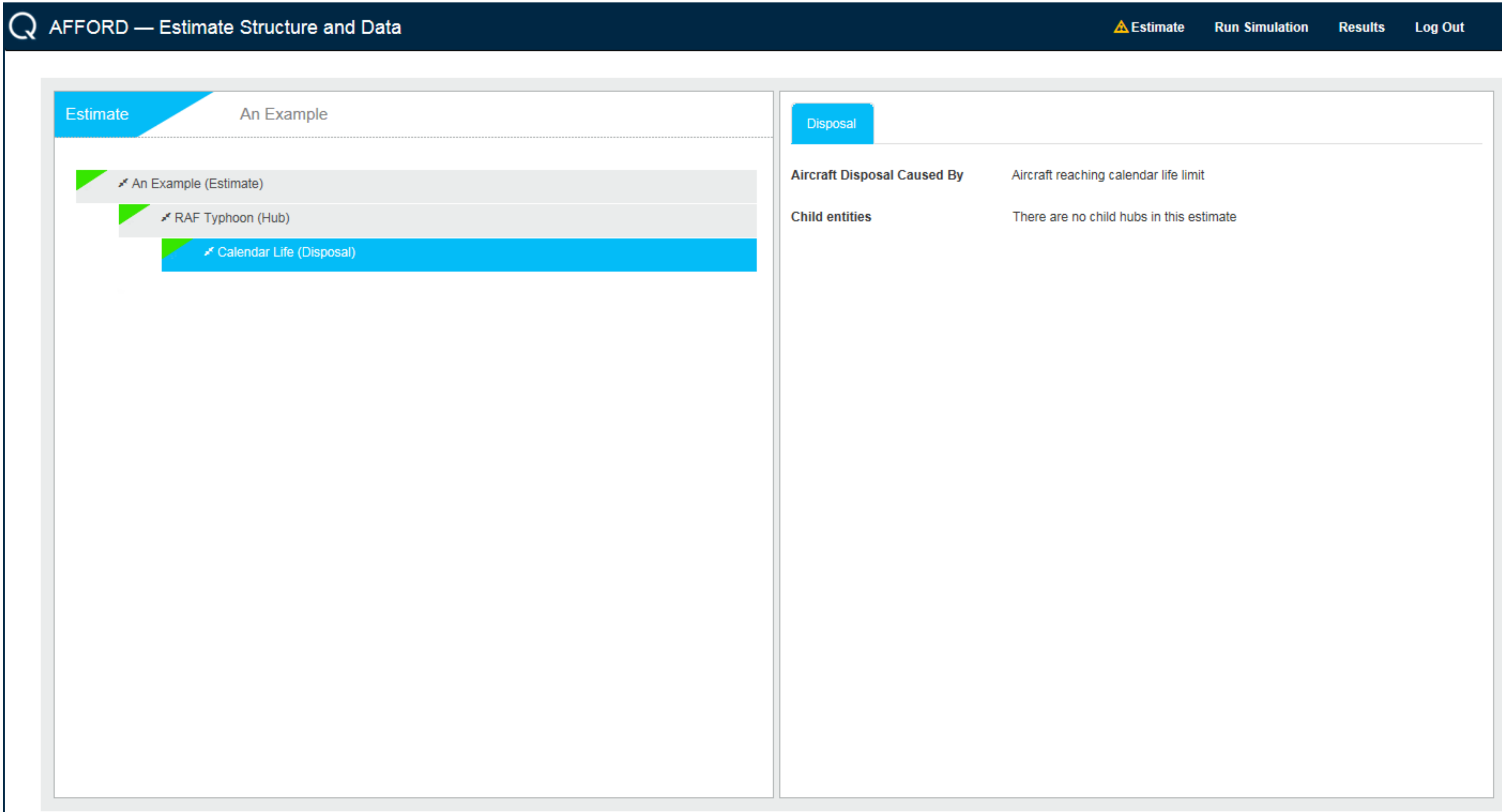
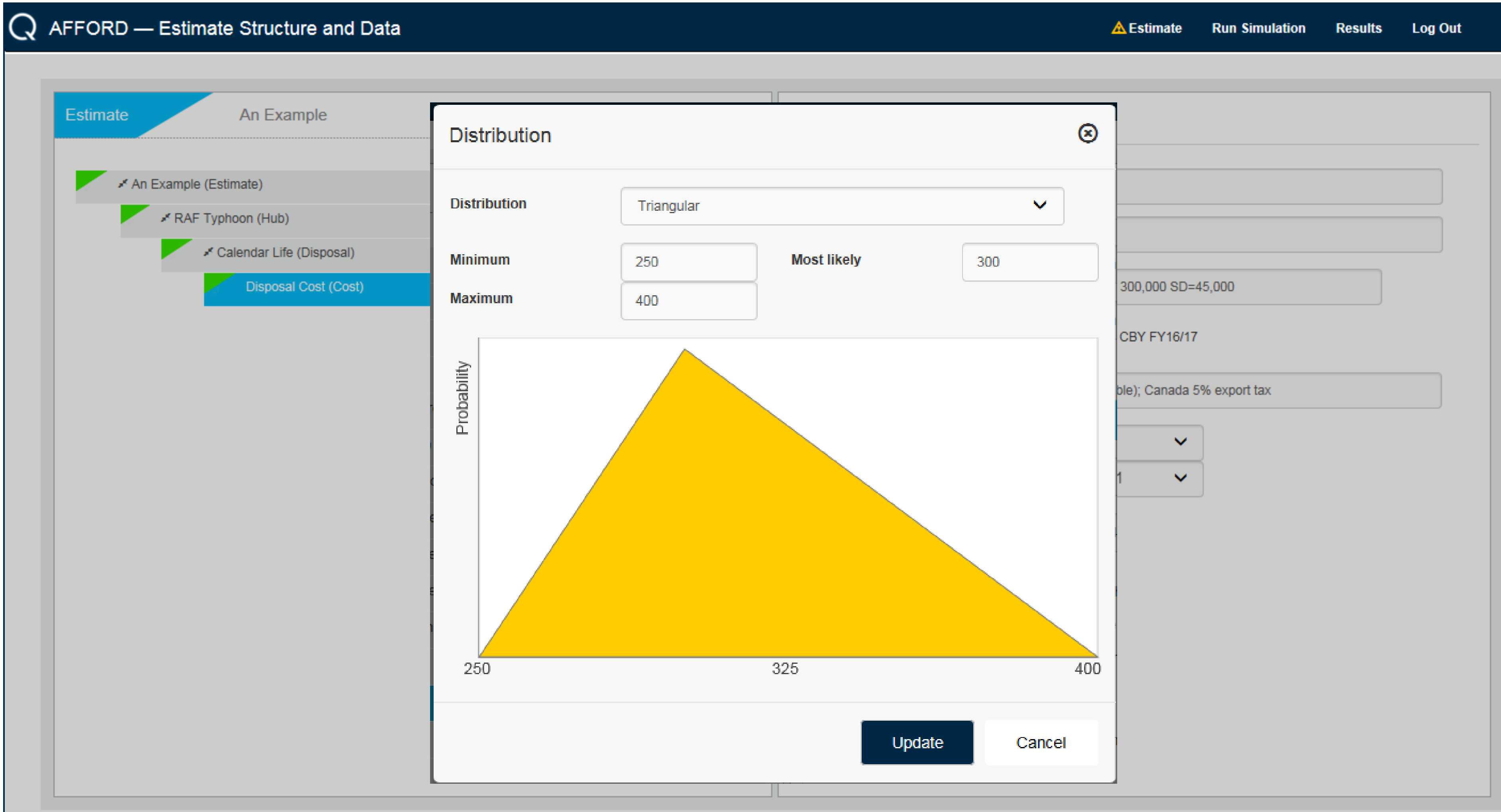
Worked example - Disposal



Worked example – Cost



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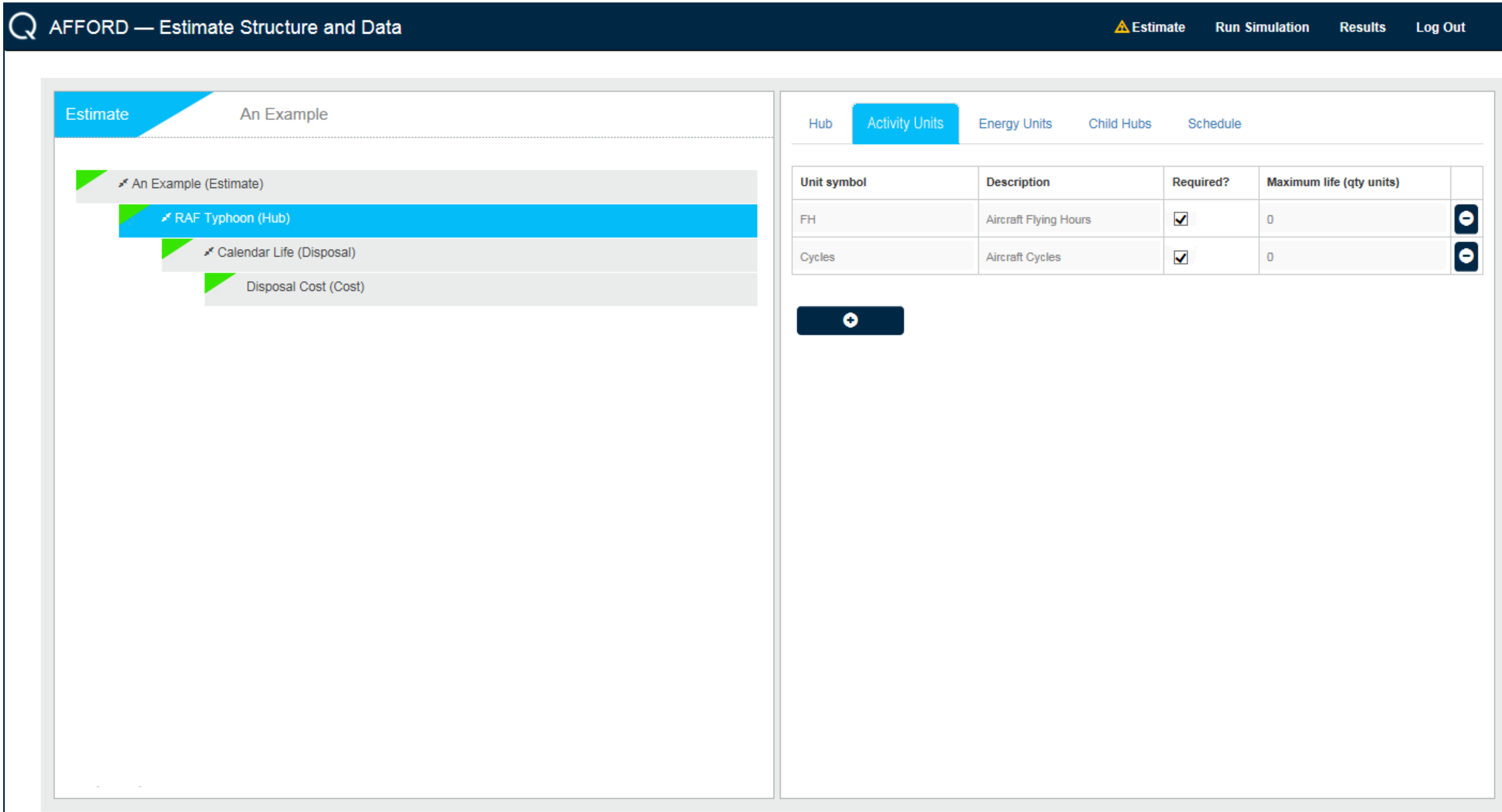
Worked example – Hub activity units



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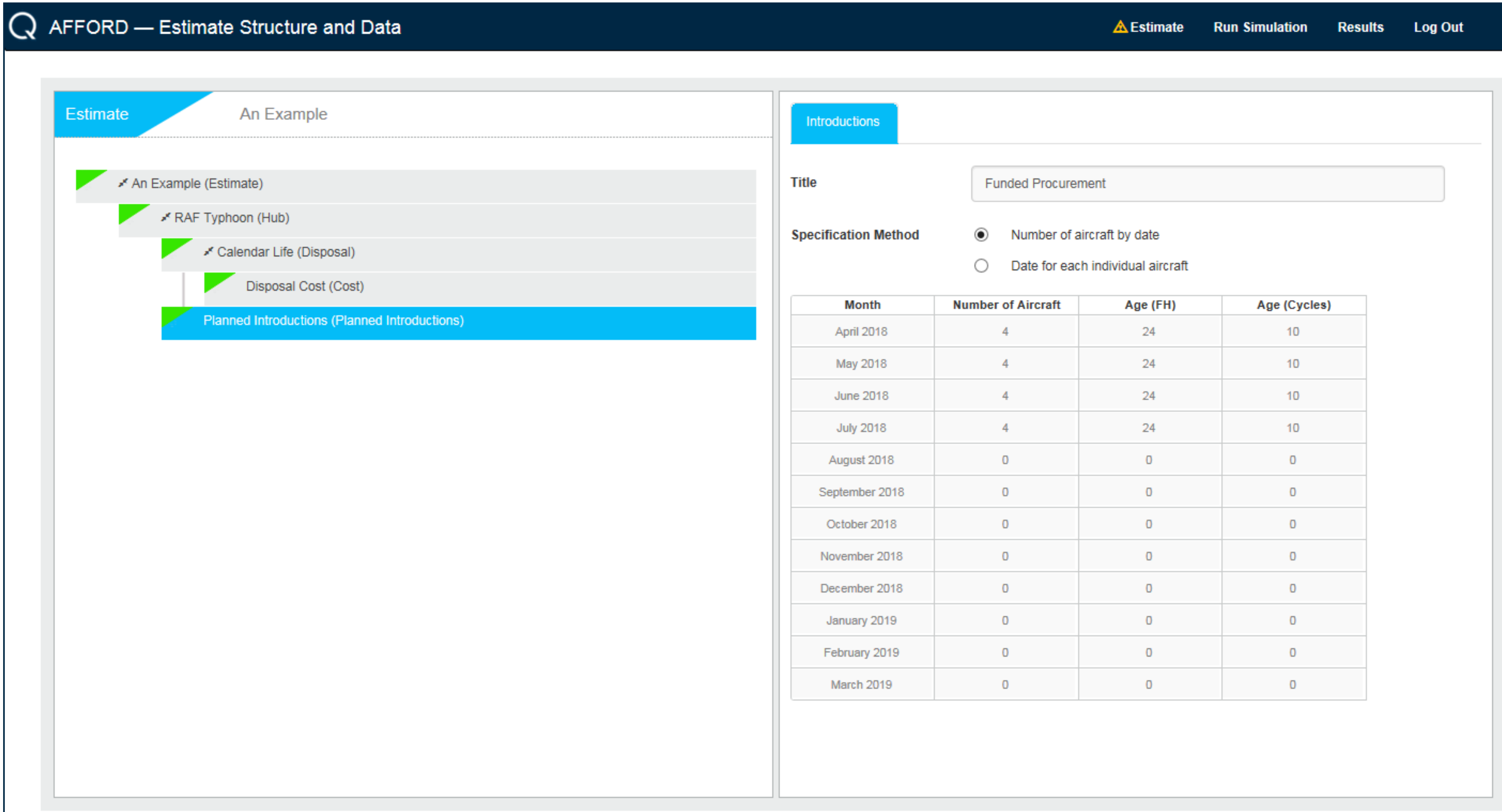
Worked example - Introductions



Month	Number of Aircraft	Age (FH)	Age (Cycles)
April 2018	4	24	10
May 2018	4	24	10
June 2018	4	24	10
July 2018	4	24	10
August 2018	0	0	0
September 2018	0	0	0
October 2018	0	0	0
November 2018	0	0	0
December 2018	0	0	0
January 2019	0	0	0
February 2019	0	0	0
March 2019	0	0	0

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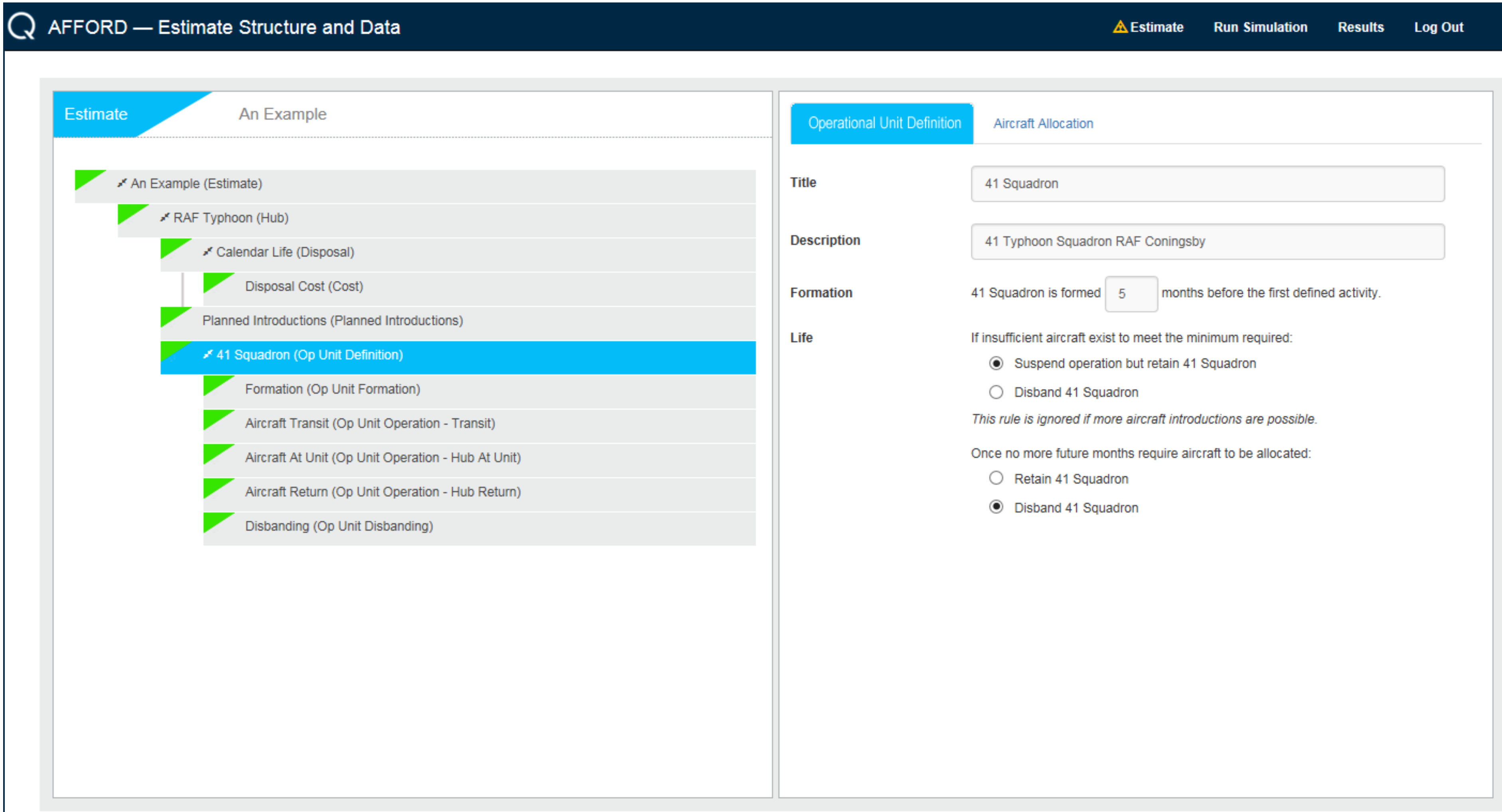
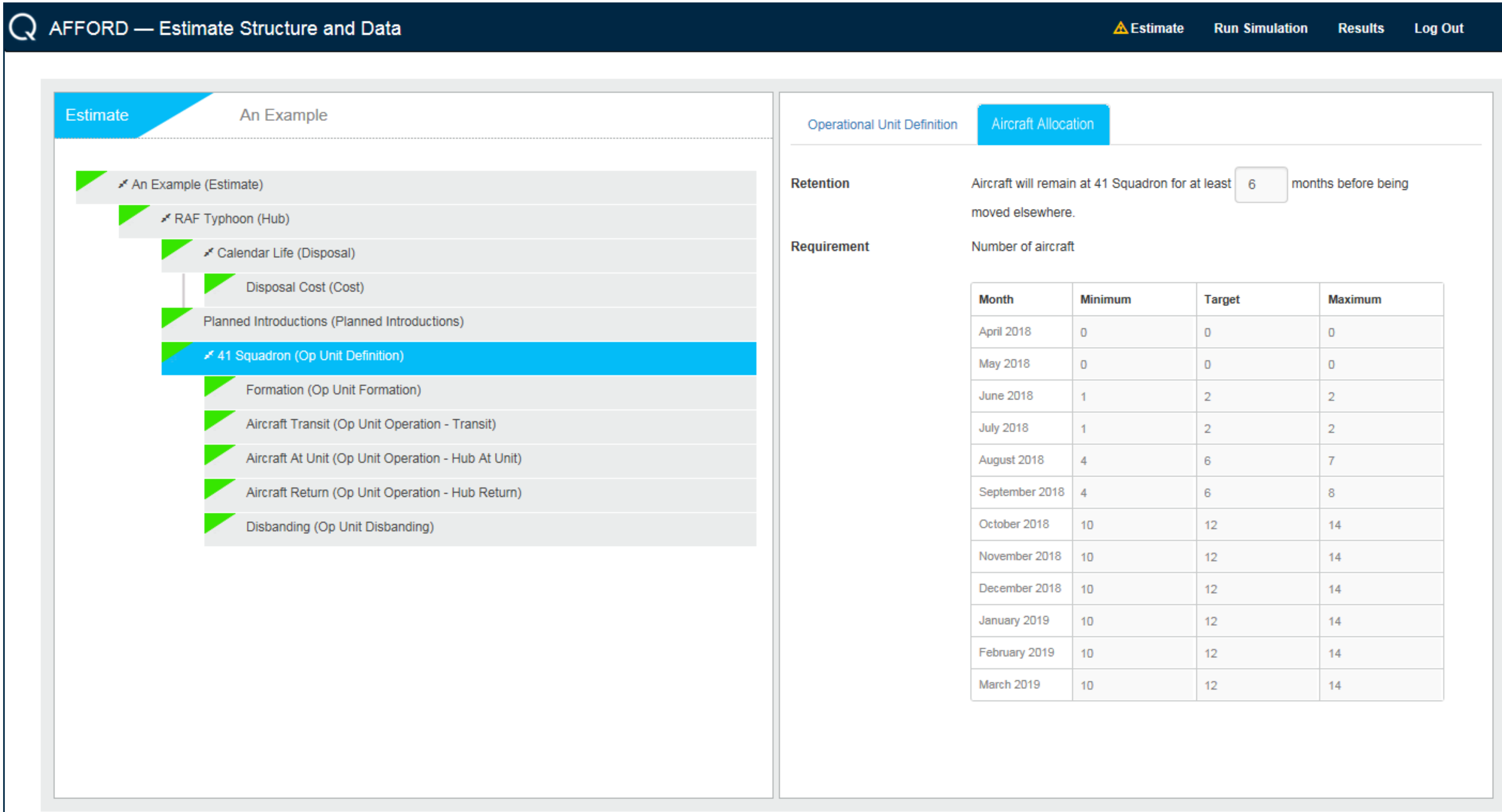
Worked example – Operational Unit



Worked example – Operational Unit entity allocation



Month	Minimum	Target	Maximum
April 2018	0	0	0
May 2018	0	0	0
June 2018	1	2	2
July 2018	1	2	2
August 2018	4	6	7
September 2018	4	6	8
October 2018	10	12	14
November 2018	10	12	14
December 2018	10	12	14
January 2019	10	12	14
February 2019	10	12	14
March 2019	10	12	14

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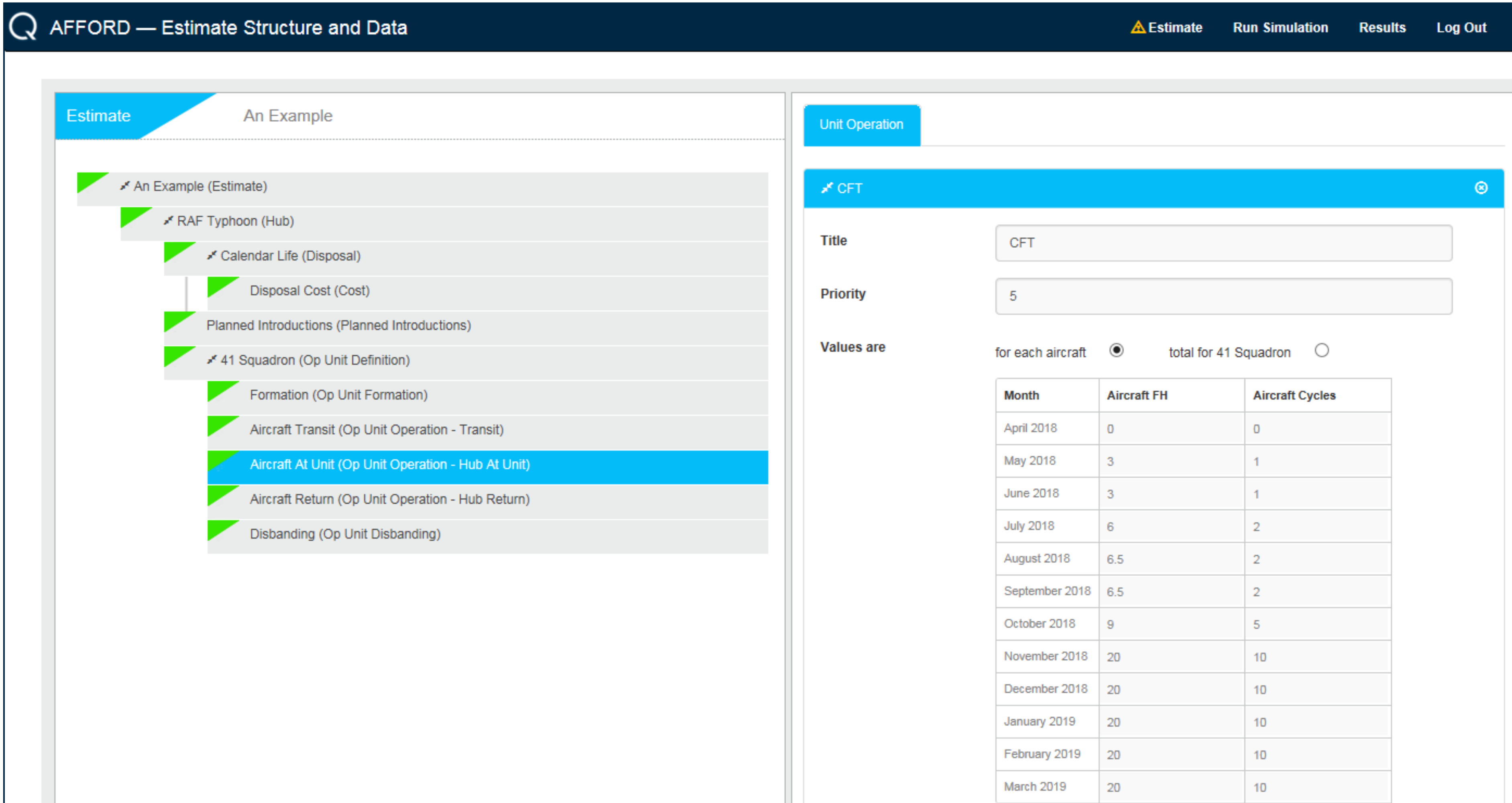
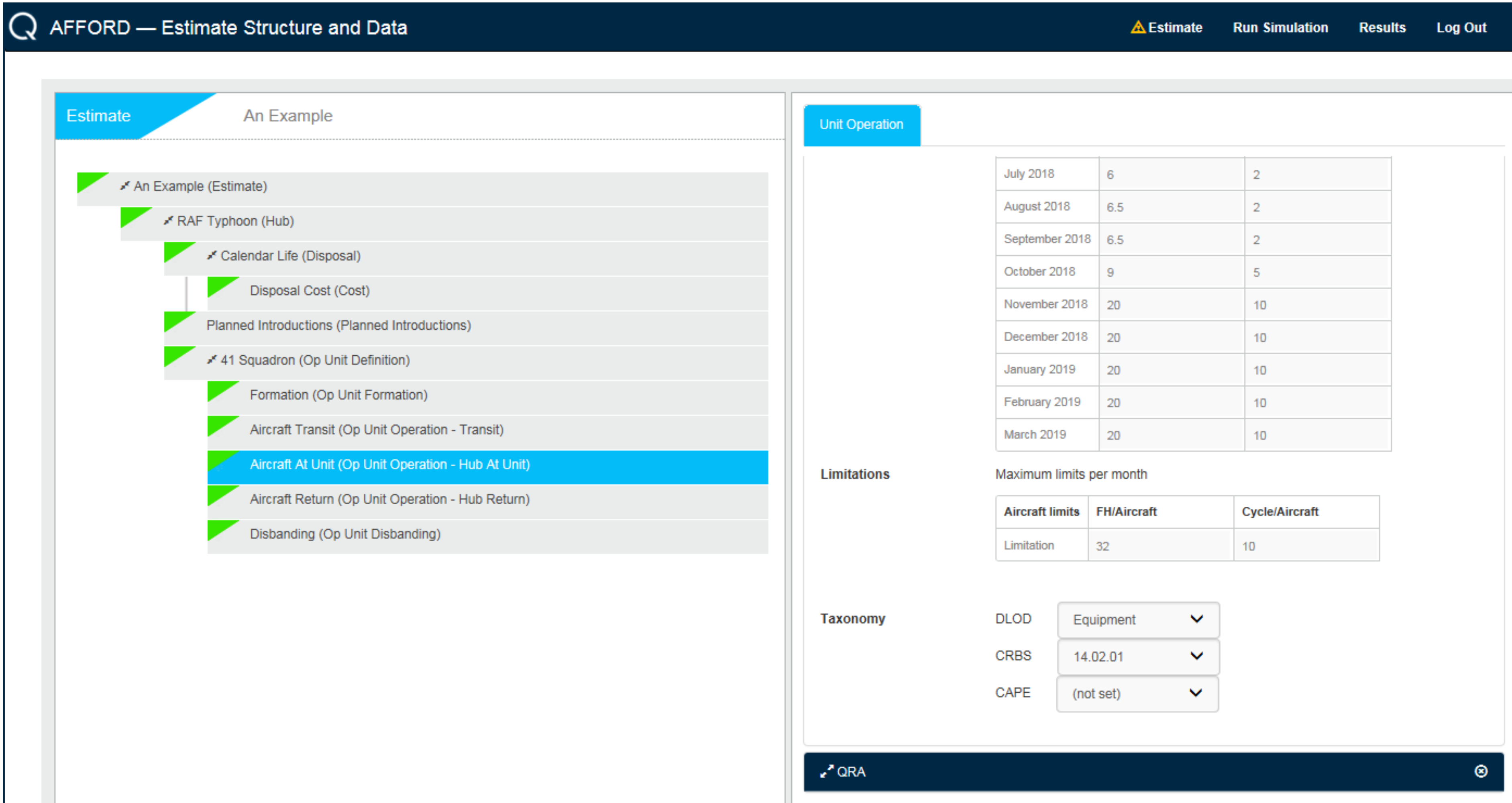
Worked example – Operational Unit operational activity



Month	Aircraft FH	Aircraft Cycles
April 2018	0	0
May 2018	3	1
June 2018	3	1
July 2018	6	2
August 2018	6.5	2
September 2018	6.5	2
October 2018	9	5
November 2018	20	10
December 2018	20	10
January 2019	20	10
February 2019	20	10
March 2019	20	10

Worked example – Operational Unit operational activity



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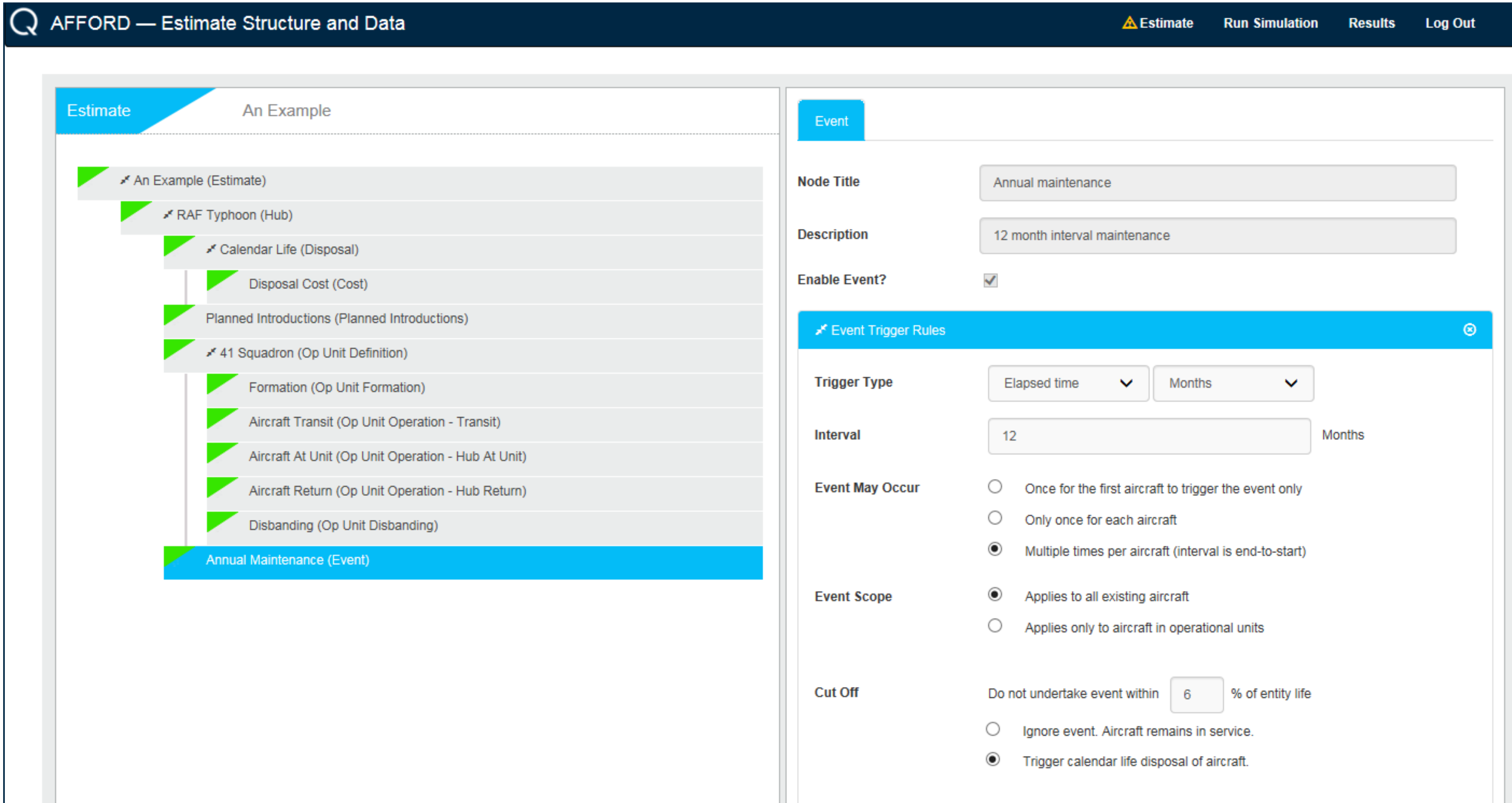
Worked example – Event trigger



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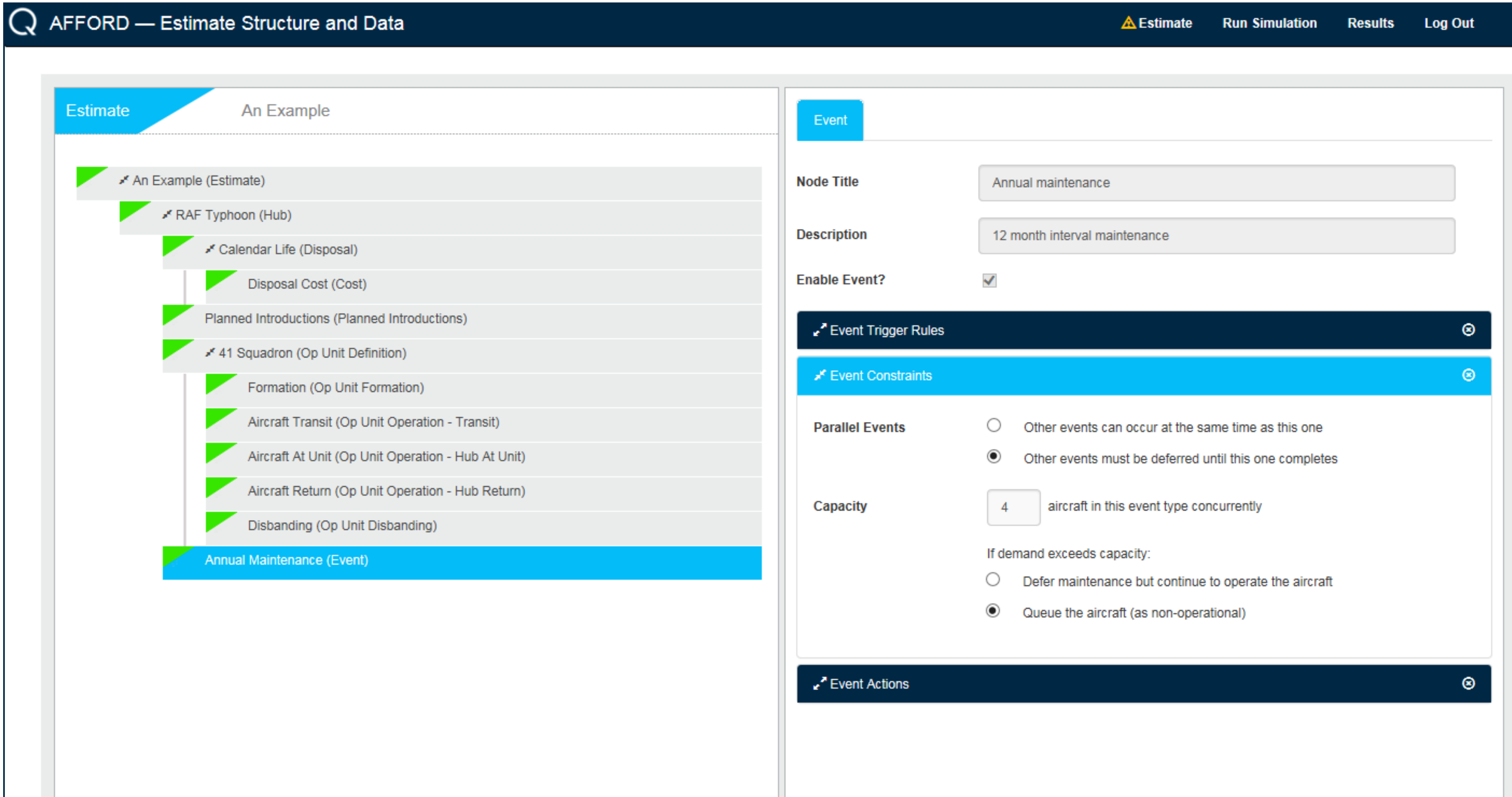
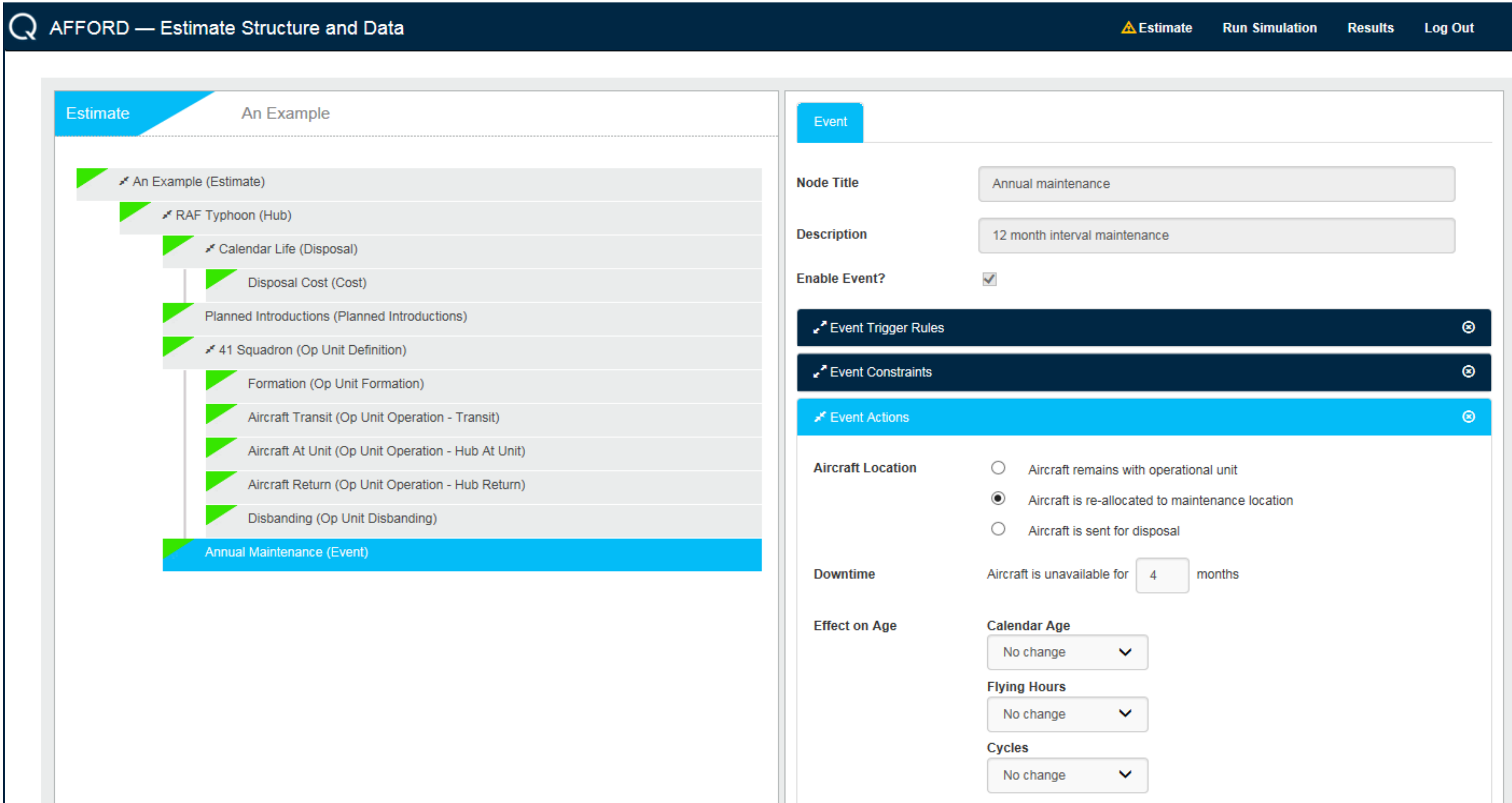
Worked example – Event constraints



Worked example – Event actions



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Worked example – Other objects

- Child hubs – engine linked to aircraft
- Reactive introductions
- Personnel grade, number and cost tables
- Non-cost object
- Save estimate as a template
- Revision history against each input, assumptions and notes
- Production of CDAL
- Uncertainty
- Correlation (any cost object, any event trigger)
- Simulation risks

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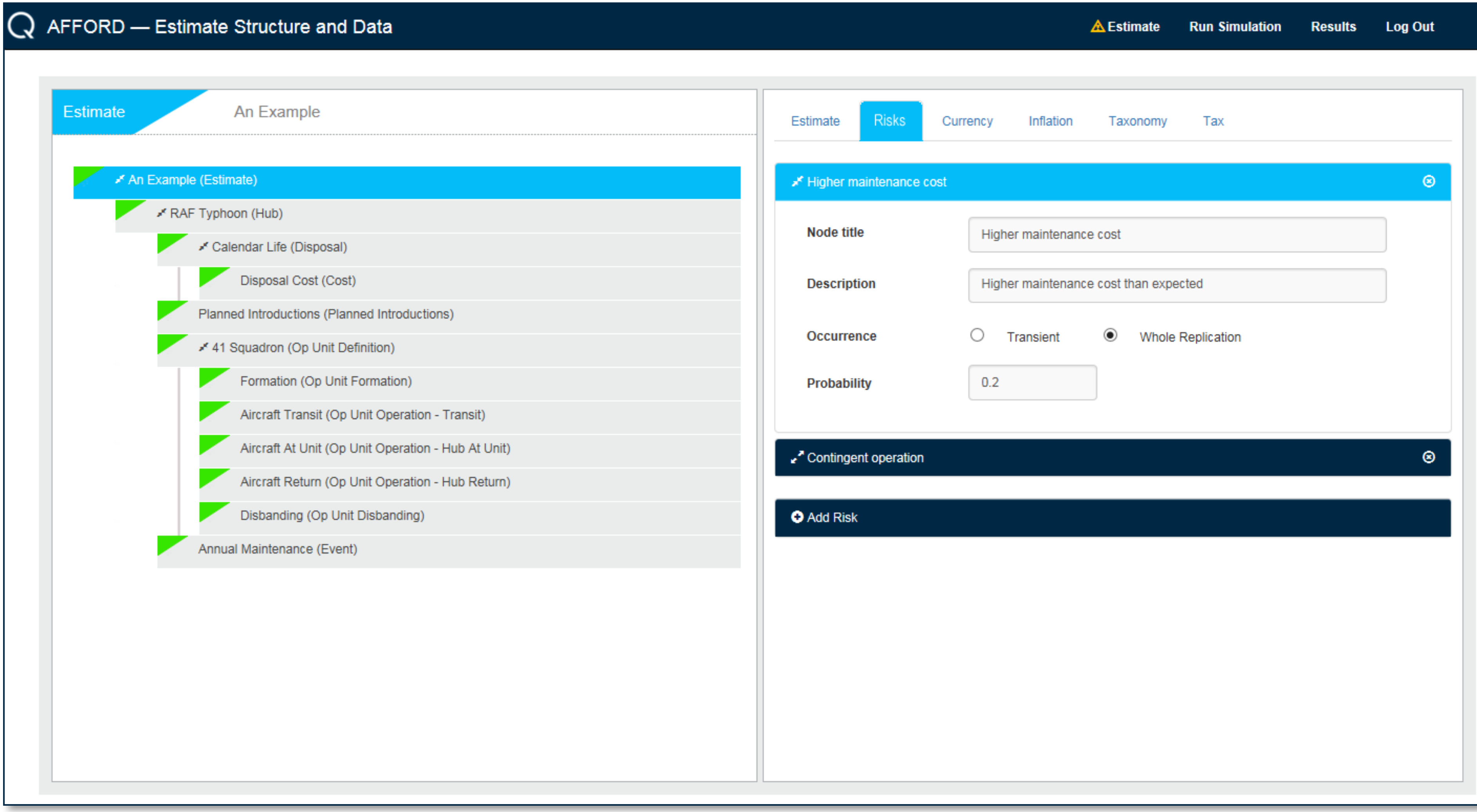
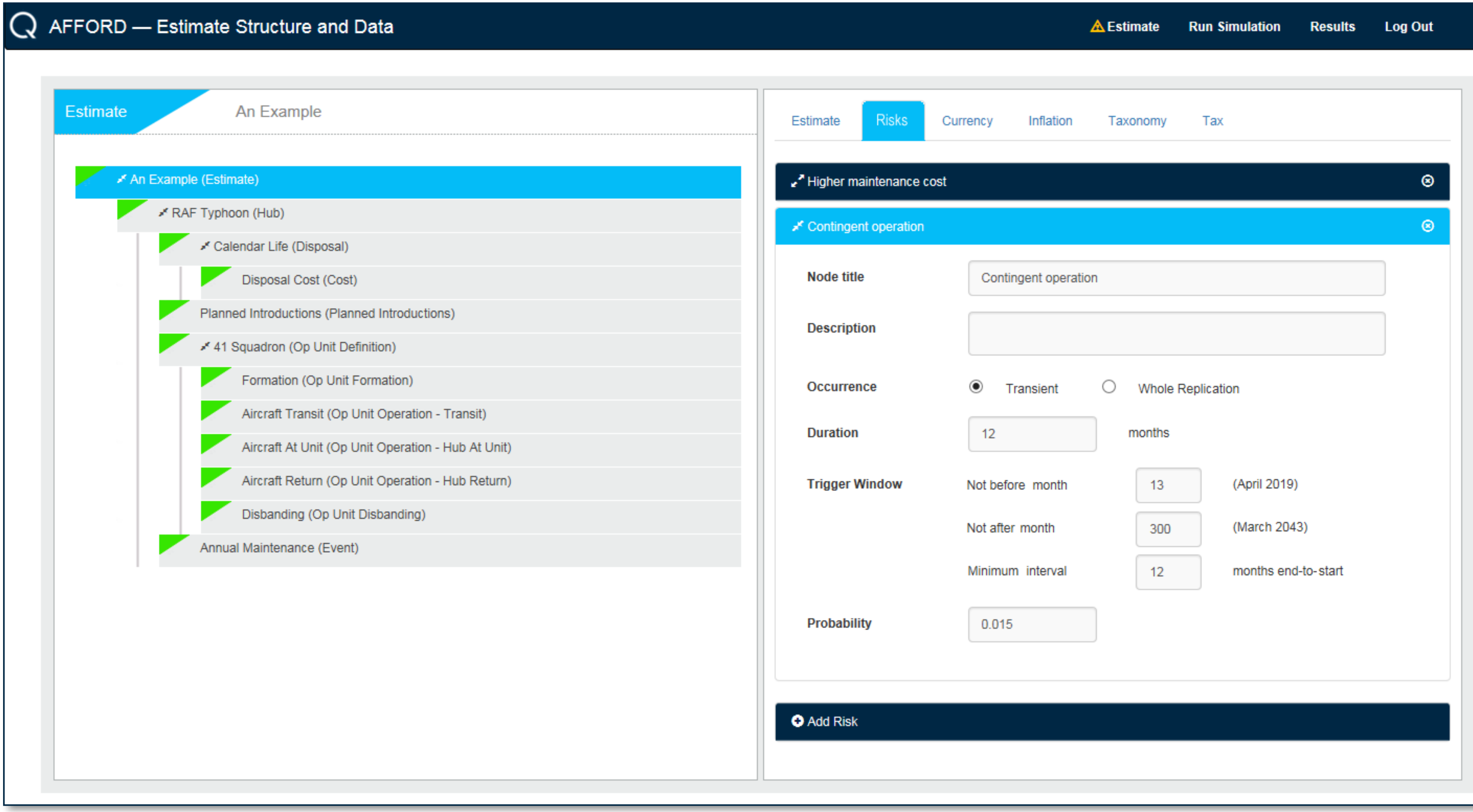
Worked example – Whole Replication Risk



Worked example – Transient Replication Risk



Worked example – Outputs

AFFORD — Estimate Structure and Data

Estimate | Run Simulation | Results | Log Out

Results

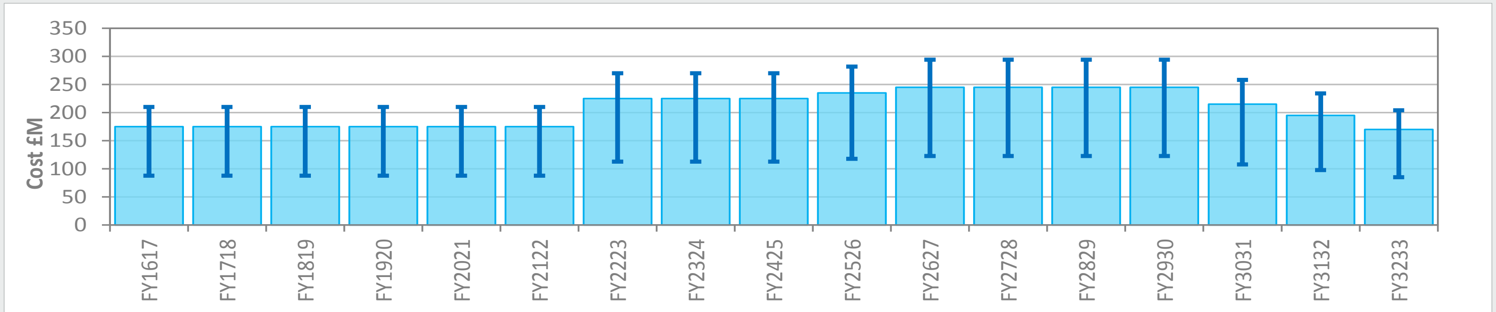
5m wind tunnel baseline estimate
Cost Base Year 2016

Percentile 50 (of the total cost) **Tails** 10 and 90 (of the total cost)

Representative replication (1,224)

Run information | Costs | Capability

	Total	FY1617	FY1718	FY1819	FY1920	FY2021	FY2122	FY2223	FY2324	FY2425
5m wind tunnel base estimate (estim	7170.00	375.00	375.00	385.00	385.00	395.00	395.00	455.00	455.00	465.00
Corporate costs (heading)	3520.00	175.00	175.00	175.00	175.00	175.00	175.00	225.00	225.00	225.00
Sub entry 1 (personnel)	3520.00	175.00	175.00	175.00	175.00	175.00	175.00	225.00	225.00	225.00
Sub entry 2 (cost)	2155.00	100.00	100.00	100.00	100.00	100.00	100.00	150.00	150.00	150.00
Sub entry 3 (cost)	2155.00	100.00	100.00	100.00	100.00	100.00	100.00	150.00	150.00	150.00
Security costs (heading)	3650.00	200.00	200.00	210.00	210.00	220.00	220.00	230.00	230.00	240.00
SSSI costs (heading)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



Settings | Output order: Original structure | Cumulative | Bar chart | Constant year | I | S

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Worked example – Outputs

AFFORD — Estimate Structure and Data

Estimate | Run Simulation | Results | Log Out

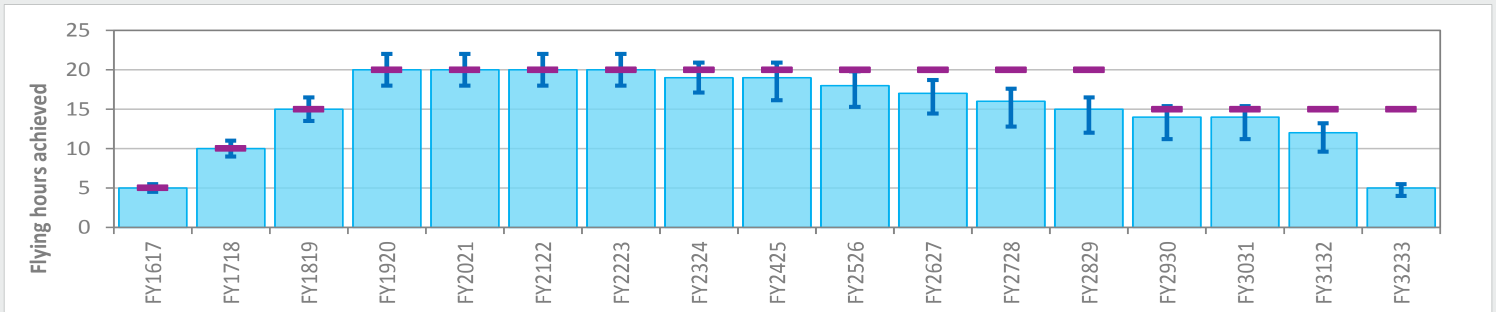
Results 5m wind tunnel baseline estimate
Cost Base Year 2016

Percentile 50 (of the total cost) **Tails** 10 and 90 (of the metric)

Representative replication (1,224)

Run information | Costs | Capability

	Total	FY1617	FY1718	FY1819	FY1920	FY2021	FY2122	FY2223	FY2324	FY2425
Hub - Aircraft										
Flying hours achieved	259.0	5.00	10.00	15.00	20.00	20.00	20.00	20.00	19.00	19.00
Flying hours target	290.0	5.00	10.00	15.00	20.00	20.00	20.00	20.00	20.00	20.00
Flying hours	(%)	100%	100%	100%	100%	100%	100%	100%	95%	95%
Cycles achieved	98.0	2.50	5.00	7.50	10.00	10.00	6.67	6.67	6.33	6.33
Cycles target	108.3	2.50	5.00	7.50	10.00	10.00	6.67	6.67	6.67	6.67
Cycles	(%)	100%	100%	100%	100%	100%	100%	100%	95%	95%
m3 F-76	31857.0	615.00	1230.00	1845.00	2460.00	2460.00	2460.00	2460.00	2337.00	2337.00
m3 F-44	3504.3	67.65	135.30	202.95	270.60	270.60	270.60	270.60	257.07	257.07



Settings | Output order: Original structure | Cumulative | Bar chart | Constant year | I | S

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Benefits of new approach

Requirement	Emergent Systems Dynamics
Robust, standardised, accurate and repeatable whole life equipment support forecasting.	Well validated individual standard components; A framework that ensures objects are only incorporated in a valid manner; Can support any part of lifecycle.
Directly links cost to programme output.	Programme outputs derived from same input as cost outputs; Constraints and feedback loops linking cost to output and output to cost.
Ability to compare equipment support costed options.	Allows comparison of user defined options; User defined taxonomy allowing comparison of outputs.
A flexible capability that can model all types of equipment support budget forecasts.	A toolkit of 'intelligent' objects that interconnect automatically to define, on the fly, an SD model; Flexibility, user defined – entity labels, object labels, energy units, activity units, multiple costs, multiple events, currencies, taxation, taxonomy, risks….
Aligns to cost estimating guidance, especially in the area of uncertainty correlation.	Uncertainty and correlation; An emergent system dynamics model that tracks individual entities (e.g. aircraft) through life using an entity based time step simulation engine; Representation of risk; Capturing changes, assumptions and production of CDAL.

Conclusion	**A substantial step forward in cost estimating**

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Benefits of new approach

- Better quality estimates
  - Unprecedented versatility in system of systems approach to generating cost models.
  - Revolutionary direct linkage between cost, schedule and system outputs.
  - Risk, uncertainty and correlation built into the fabric of the tool.
  - Accurate and repeatable whole life equipment support cost forecasting.
  - Aligning modelling outputs to approvals process.
- Quicker and cheaper cost estimates
  - Reducing reliance on bespoke models, removing the need for repeated validation of multiple models.
  - Flexible input methodology allows any programme to be modelled at the appropriate level of detail.
- Shared understanding to facilitate improved corporate memory
  - Use of a standard toolset ensures users can immediately understand and use another estimate.
  - Expertise is transferable across programmes: facilitating team working.

- This new approach to equipment support cost modelling helps senior decision makers who want to better manage complex budgets and costs by directly linking operational output and costs over time, whilst reducing the time taken to produce an accurate estimate.

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Questions ?

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