Capturing the Technology Risks of Advanced Weapon System Projects

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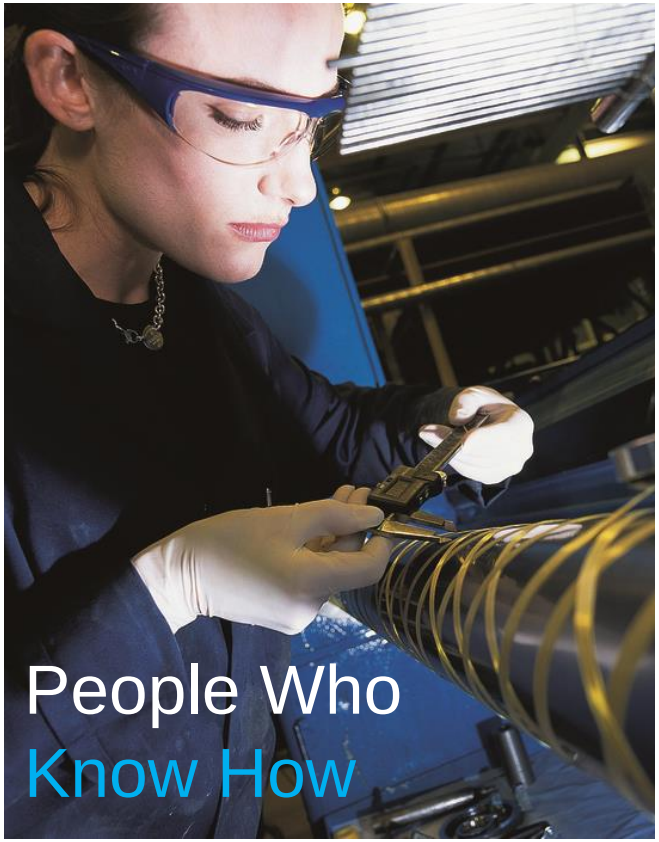

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Background

Source: http://wtc.qinetiq.com/Pages/default.aspx

- UK MoD continues to pursue the development of complex weapons - dependent on innovative technology
- Successful outcomes require an R&D base capable of maturing the required technology base for each stage of development
- TMAF has been developed to allow MoD to identify the risks inherent in technology maturation

Scope of Presentation

- The operational requirements, development timescales, concepts and specific technologies which TMAF was developed to assess are sensitive and cannot be discussed in this forum
- This presentation focusses on the TMAF methodology and its applicability to all types of complex weapons
- All data and outputs presented have been generated by QinetiQ for illustrative purposes only

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WSTC Weapon System Study

- Commissioned by Dstl through the Weapons Science and Technology Centre (WSTC): http://www.wstc.qinetiq.com/Pages/default.aspx
- Study of innovative weapon system concepts
- Contracted under WSTC with Thales as industry lead
- QinetiQ workstrand lead for development of “Technology Maturity Assessment Framework” (TMAF)

Technology Maturity Assessment

- Advanced weapon system concepts required the development and integration of new technologies
- *Technology maturation* is the process of bringing technologies up to the appropriate "Technology Readiness Level" (TRL) for each stage of concept development
- *Technology risk* is the risk that technologies fail to mature to the required TRLs in the required timescales; broken down as:

- **Cost risk:** Can maturation be completed within the envisaged level of funding?
- **Time risk:** Can the activities (if funded) be completed within the specified timescales (or at all)?
- **TRL shortfall risk:** Are the emerging TRLs high enough to provide the required weapon system functionality at each key development milestones?

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TRL definitions

TRL	Definition
1	Basic principles observed and reported.
2	Technology concept and/or application formulated.
3	Analytical and experimental critical function and/or characteristic proof-of-concept.
4	Technology basic validation in a laboratory environment.
5	Technology basic validation in a relevant environment.
6	Technology model or prototype demonstration in a relevant environment.
7	Technology prototype demonstration in an operational environment.
8	Actual Technology completed and qualified through test and demonstration.
9	Actual Technology qualified through successful mission operations.

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Keeping track of TRLs

Current TRL – The TRL at the starting date for the TMAF assessment

Expected TRL – The expected TRL at each stage of technology maturation, as a consequence of continued reasonable investment in the technology, allowing for the usual technology maturation rates.

Required TRL – The required TRL in order to meet a defined concept development milestone, e.g. a Main Gate submission in June 2018.

Technology Maturity Assessment Framework

- **Objective:** Develop and implement an analytical framework to enable assessment of each downselected concept for technical maturity.
- Drivers:
  - Required performance and capability enablers
  - TRL required for each sub-system within the concept architecture.
  - Current and predicted future TRLs
- "Gap between required and current status will be measure of technical risk associated with the concept"
- QinetiQ IPR
  - DEFCON 705 (Full Rights)

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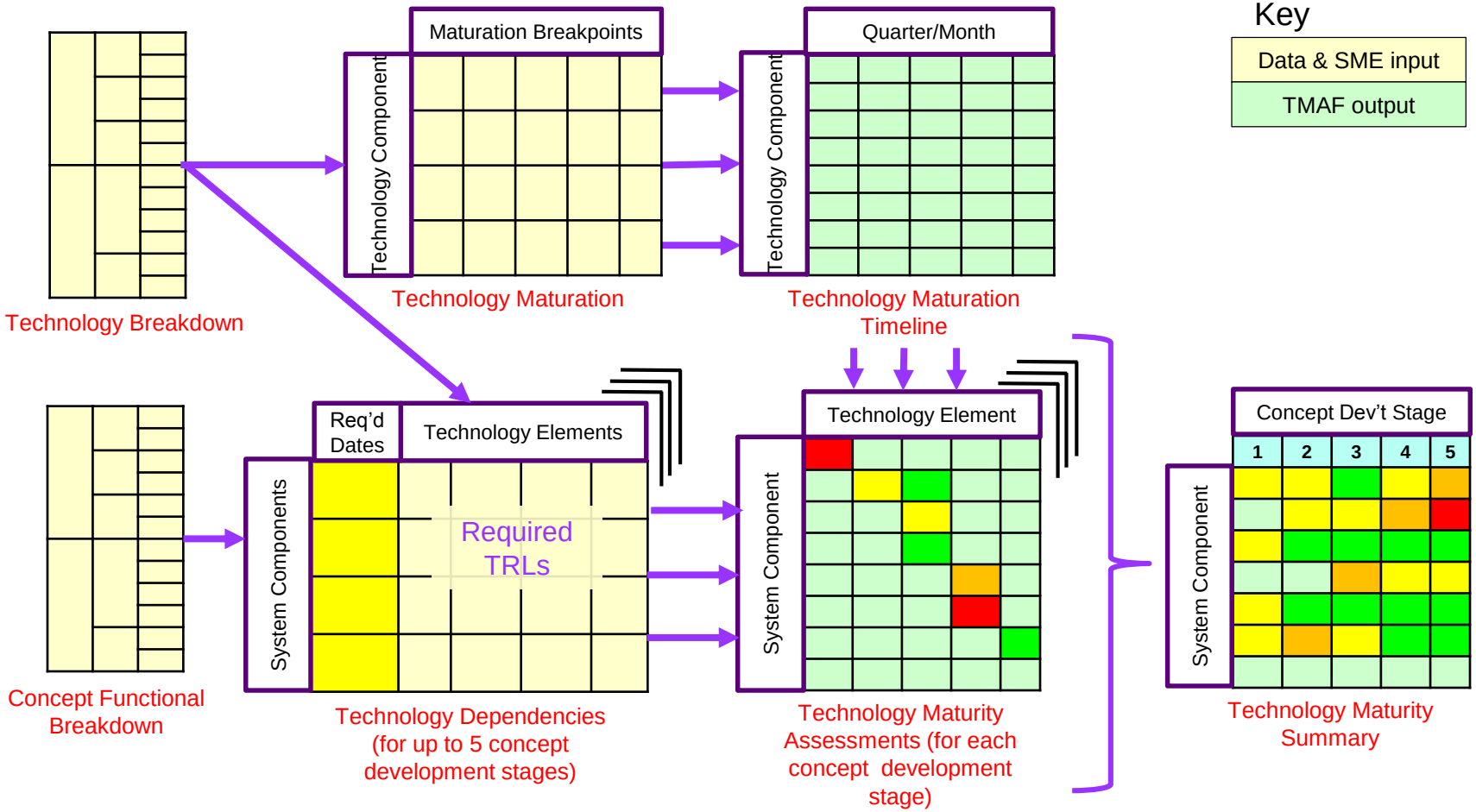
TMAF Process: Overview



Input: Technology Breakdown

Technology Domain	Technology Area	Technology Group	Technology	Technology Element
Weapon technology base	Effector	Damage mechanism		
		Delivery of effect		
		Effector pointing	Traverse and elevation	
			Aimpoint maintenance	
		Damage evaluation		
		Rate/volume of fire		
	Targeting	Target tracking	Tracking sensors	High-res sensors
				Track data fusion
			Multi-target tracking	
			Sensor integration	Sensor data interface
	Fire control	Weapon director	Director control	Director azimuth control
				Director elevation control
			Director stabilisation	
			Director integration	Data interface
	Platform interface	Power supply	Primary power source	
		Ammunition supply		

Hypothetical data

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Input: Concept Functional Breakdown

System Type	Functional area	System	Module
Complex weapon	Weapon installation	Effector	Damage mechanism
			Delivery to target
		Target Acquisition	Cueing
			Target capture
		Target tracking	Tracking system
			Multi-target tracking
		Fire control	Fire control solution (FCS) generation
			Effector pointing
			Aimpoint maintenance
		Multiple engagements	Multi-target engagement
			Engagement cycle time
	Platform	System enablers	Power supply
			Physical interface
		Surveillance	Wide-area surveillance
			Tactical surveillance
			Threat evaluation
			IFF
		C3	Communications

Hypothetical data

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Input: Technology Maturation Data

- Maturation of each technology component expressed in terms of "Maturation Breakpoints":
  - Expected TRL + target date for this to be achieved
- Breakpoints may be derived from:
  - SME knowledge of existing/planned research
  - The technology maturation drivers for the concept being assessed
- Optional data fields for cost and time risk
  - Captures confidence that Expected TRL will be achieved at specified date and within available funding – either or both may be entered
- Adaptable to available data
  - Maturation risk returns a null output if no data entered
  - Default risk assessments are made if data are incomplete

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Input: Technology Maturity Datasheet

Technology Element	Est. Current TRL	Assessment date:	22/07/2015					
		ration Breakpoint 2:	Funded Technology Demonstration Programme (TDP) completion					
		Expected TRL	Breakpoint MMM YYYY	Development risks to Breakpoint 2: Activities required	Risk areas	Mitigations	Risk assessment (0-9) Cost	Time	Overall
Damage mechanism	4	6	Jun 2018	Funded TDP	Solution may fall short of performance goals. Tight timescales	Review performance goals at proof-of-concept stage.		5	5.0
Delivery of effect	3	6	Jun 2018	Funded TDP	Safety issues with current test facilities.	Generate safety case for required enhancements. Set aside contingency funding.	5	6	6.5
Traverse and elevation	3	6	Jun 2018	Engineering demonstrator	Need new test rigs - funding not identified	Test at limited traverse & elevation rates & extrapolate results		4	4.0
Aimpoint maintenance	4	6	Jun 2018	Customisation of commercial technology	Solution may fall short of performance goals	Review performance goals at proof-of-concept stage.		4	4.0
Damage evaluation	3		Jun 2018	Funded TDP	Difficult to demonstrate without a working prototype	Demonstrate using simulated functionality		3	3.0
Rate/volume of fire	4	6	Jun 2018	Engineering demonstrator	Solution may fall short of performance goals	Review performance goals at proof-of-concept stage.		4	4.0

Hypothetical data

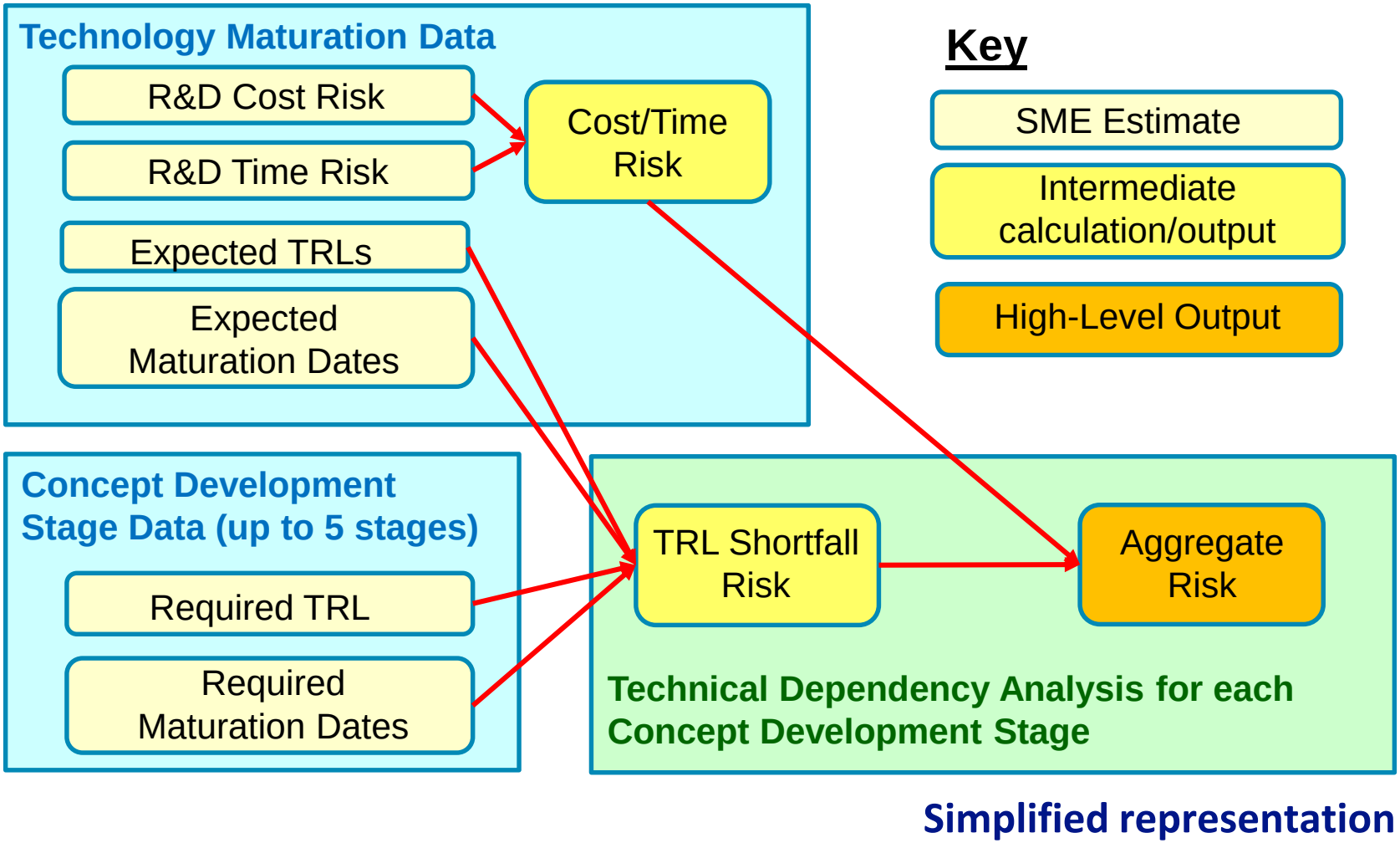
Input: System Component Dependencies

Concept Functional Breakdown		Enabling Technology Maturation Target Date		Enabling Technologies					
				Damage mechanism	Delivery of effect	Target tracking			
Functional area	Component	Month (1-	Year	Damage mechanism	Delivery of effect	High-res sensors	Track data fusion	Multi-target tracking	Sensor data interface
Weapon installation	Damage mechanism	9	2020	7					
	Delivery to target	9	2020		7				
	Cueing	9	2020						7
	Target capture	9	2020			7			7
	Tracking system	9	2020			7			
	Multi-target tracking	9	2020				7	7	
	Multi-target engagement	9	2020				7	7	

Hypothetical data

- Identifies technology dependencies of each system component at each of up to 5 concept development stages
- Dependency expressed as Required TRL (1-9) and date at which this should be achieved (allowing lead time for integration into overall system)

Working – Technology Maturation Risk Calculations



Simplified representation

Technology Maturation Risk Level Definitions

- Risk estimates from Subject-Matter Experts (SME) are elicited using a qualitative 1-9 scale
- TMAF combines the SME risk inputs with the timescales for technology maturation and concept development to generate “Aggregate Risk” outputs on the same 1-9 scale

1	No significant risks
2	Minor risks with clear mitigations
3	Moderate risks - mitigations identified
4	Moderate risks - further mitigations needed
5	Significant risk to successful outcome
6	Significant risk to acceptable outcome
7	Major risk - successful outcome improbable
8	Major risk - acceptable outcome improbable
9	Extreme risk - no realistic probability of acceptable outcome

Shortfall Risk

- Shortfall Risk assigns a risk score >1 when the Expected TRL for a technology is less than the Required TRL at a Concept Development Stage
- TMAF calculates Shortfall Risk from the lookup table below

Required TRL	Current TRL									
	No prediction	1	2	3	4	5	6	7	8	9
1	1	1	1	1	1	1	1	1	1	1
2	1	2	1	1	1	1	1	1	1	1
3	1	3	3	1	1	1	1	1	1	1
4	1	5	5	3	1	1	1	1	1	1
5	3	7	6	5	3	1	1	1	1	1
6	5	8	7	7	5	3	1	1	1	1
7	7	9	8	8	7	5	3	1	1	1
8	8	9	9	9	8	7	5	3	1	1
9	9	9	9	9	9	8	7	5	3	1

Output: Technology Maturation Timeline

Technology Element	2018			2019				2020				2021			
	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Damage mechanism	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7
Delivery of effect	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7
High-res sensors	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7
Track data fusion	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7
Multi-target tracking	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7
Sensor data interface	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7

Hypothetical outputs

- TMAF generates a visualisation of the Expected TRL of each enabling technology
- Table entries are Expected TRL at end of specified quarter
  - e.g. Expected TRL for Delivery of Effect at end of 2020 Q2 is 6
- Colour-coded indicates Cost/Time risk associated with each Expected TRL
  - e.g. there is a Major Risk (Level 7 or 8) that the TRL for Delivery of Effect at end of 2020 Q2 will be less than 6

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Detailed Output: Technical Dependency Analysis

Functional area	Component	Required date for Technology Maturation	Max combined risk	Damage mechanism	Delivery of effect	Target tracking			
				Damage mechanism	Delivery of effect	High-res sensors	Track data fusion	Multi-target tracking	Sensor data interface
Weapon installation	Damage mechanism	Sep 2020	4.0	4.0					
	Delivery to target	Sep 2020	5.0		5.0				
	Cueing	Sep 2020	3.0						3.0
	Target capture	Sep 2020	3.0			3.0			3.0
	Tracking system	Sep 2020	3.0			3.0			
	Multi-target tracking	Sep 2020	4.0				3.0	4.0	
	Multi-target engagement	Sep 2020	5.0				3.0	4.0	
	Engagement cycle time	Sep 2020	5.0						

Hypothetical outputs

- Generated for each Concept Maturation Stage
- Shows Aggregate Risk (Cost/Time Risk + Shortfall Risk) colour-coded according to risk level (1, 2 = green, 3,4 = amber, etc.)

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High-Level Output: Maturation Risk Summary

System Functional Breakdown		Concept Development Stage 1	Concept Development Stage 2	Concept Development Stage 3	Concept Development Stage 4
Functional area	Component	Initial Gate submission	Main Gate submission	Range Trials	Acceptance
		Mar 2016	Jun 2018	Sep 2020	Dec 2022
Weapon installation	Damage mechanism	5.5	5.0	4.0	3.0
	Delivery to target	6.0	6.5	5.0	4.0
	Cueing	1.0	1.0	3.0	2.0
	Target capture	3.0	3.0	3.0	4.0
	Tracking system	3.0	3.0	3.0	4.0
	Multi-target tracking	1.0	4.0	4.0	4.0
	Multi-target engagement		4.0	5.0	4.0
	Engagement cycle time		4.0	5.0	2.0
Platform	Power supply		1.0	1.0	4.0
	Physical interface		5.0	4.0	5.0
	Communications		1.0	3.0	2.0

Hypothetical outputs

- Shows **maximum** Maturation Risk across the technology base for that component

Summary - Functionality

- Key inputs
  - Technology and Functional Breakdowns
  - Maturation Breakpoints for key enabling technologies
  - Up to 5 development stages for concept being assessed
  - Technology dependencies (TRL n by month m of year y) for each Concept Development Stage)
- Outputs
  - Technology maturation timelines with associated cost/time risk
  - Maturation risk (cost/time/TRL shortfall) for each technology dependency in each Concept Development Stage
  - Summary of maturation risk to each functional component at each Concept Development Stage

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Summary – Benefits and Exploitation

- TMAF is a completely generic framework for evaluating technology maturation risk
  - Applicable to any type of complex weapon or system over any timescale
  - Full flexibility in defining concept and technology breakdowns
  - Updatable as programme advances
  - Works with incomplete data
  - Identifies gaps in knowledge
- Proven in WSTC Weapon System Study

Any Questions?

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