

1810310 Timberlake J Principles OME

by Jordan Timberlake

FILE	12387_JORDAN_TIMBERLAKE_1810310_TIMBERLAKE_J_PRINCIPLES_OME_233318_1138046449.PDF (1.1M)		
TIME SUBMITTED	23-JUL-2020 06:23PM (UTC+0100)	WORD COUNT	6712
SUBMISSION ID	131810012	CHARACTER COUNT	45826

Principles of OME

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Requirement for a guided bomb was implemented. This document suggested the process involved in taking requirement to decommissioning. Realisation of a weapon into service is a substantial undertaking: a systemic, analytical approach to meet requirement at each lifecycle stage was considered. Requirements of the system must benchmark against relevant standards; consideration to the environment and Carbon zero manufacture.

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1 INTRODUCTION

1.1 SCOPE

Requirement for a guided blast/fragmentation bomb was implemented. This document suggested ideas on the process involved in taking military requirement from request through service to decommissioning and disposal. Realisation of a new weapon to be bought into service is a substantial undertaking requiring a menagerie of supporting documentation, testing, configuration, assessment and trials. This document provides conceptual proposal of the type of activity to be considered in the delivery of a new weapons system.

1.2 METHODOLOGY

To appropriately assess a requirement through service to disposal or function requires a systemic and all-encompassing lifecycle approach [CADMID/T]. The planning and works to produce a concept, fulfil an option study, define a design, rationalise each assembly design manufacture et al. far exceeds the requirement of this document. A delivery of a modern engineered system has been process driven wherein key elements or staged gates will be demonstrated to the customer and/or project lead ensuring essential works have been completed at defined sections of the process to ensure focus remains on the task.

Methodology has taken an overview type focus:

Definition of the requirements: Acquisition of requirement statements, interpretation and derivation to design function and material requirements to give a synopsis of requirements capture for a commercial aspect of delivery of a system and a selection of potential considerations to be assessed and agreed with the customer in a formal contractual context.

Requirements to conceptual design: Demonstration of concepts to meet requirement, this process is usually retained to indigenous operation and must be completed prior to presentation.

Conceptual design proposal: an epitome of the usual content contained within a conceptual proposal, from a commerce perspective it may be viewed as a technical sales pitch

Design testing: overview of types of tests and trials completed on modules components and sub-assemblies prior to testing of the full collective system against defined and agreed requirements. The expanse of this subject again intimated the necessitate to deliver a focussed section in lieu of a prodigious ensemble.

User interface: the most important requirement above even that of primary function is how the system assimilates to manufacture, service life inclusive of arena operation, and disposal. More specifically related to safety. [1, 2]

The design process as a whole is a comprehensive interminable process involving but not limited to; full option studies, justification and analytical quantified endorsement of each component level decision, following this computational modelling of function, engineering modelling and geometrically dimensioned and toleranced drawings must be produced in accordance with BS8888 to enable testing and manufacture. Given the depth of this stage in the process it could not be appropriately represented so has been omitted.

1.3 LIMITATIONS

As alluded to in 1.2 and contextually referenced throughout: Given the substantial amount of work supporting the delivery of a system through active service is a substantial undertaking requiring years of work from a diverse and substantial workforce pertaining multiple companies, agencies, governmental departments and technical disciplines. This is not a guide to bringing a system into service more of a conceptual introduction into the principals involved during the process. Joint service publications DEFSTAN publications and STANAG publications (such as 4432 : 0) are guidance to process and control measures involved in delivery of a new system. [3]

1.4 CUSTOMER REQUIREMENTS

The customer requirement received was:

"Military requirement have been raised for:

A guided targets blast/fragmentation bomb to be delivered by specified aircraft for the attack of buildings of specified design" [2, 4]

1.5 TARGET DEFINITION

Target was defined as a modern modular building comprised of steel framing, clad with a lightweight non defensive type cladding i.e. sheet metal, composite or glass. This was rationalised with the application of these modular convergent buildings in defence company, industrial and commercial estates. Often protection is given to the operational and storage facilities containing systems, but opportunity was sought to the human asset involved in integrating and delivery of the system. These buildings are multipurpose and can be refit in a short term to serve an alternate purpose, i.e. Labs, offices or machine shops et al. for the purpose of the assessment a glass clad building will be assessed an example of this would be Pyongyang Sunan International Airport terminal 2.



FIGURE 1 A general view of the newly built terminal of Pyongyang International Airport.



FIGURE 2 internal view of Pyongyang International Airport terminal.



FIGURE 3 Example of vulnerable target contained in the terminal

1.6 DELIVERY PLATFORM DEFINITION

Recent introduction of 5th generation jet fighters into the RAF and Royal Navy such as Lockheed Martin's F-35 lightning II requires application should be compatible with these type aircraft and where possible become 'future ready' to enable application to 6th generation jet fighters in addition to unmanned applications such as the future combat air system and protector RG. 1 [5]



FIGURE 4 F35 lightning IIB



FIGURE 5 Protector RG

Given the compatibility requirement an interface or launching unit was implemented as is shown with the missiles above wherein mechanical retention, launch/release/Load mechanism, were retained as a

standardised system to reduce manufacturing variants and additional cost. Due to a modular system type approach; interface units were applied in that the computer biased element would effectively have a translation system to allow the control unit to be accessed and a mounting system that can be made as an adapter to physically fit to the aircraft. This approach required minimal airframe modification and hence reduced costing. [6]

1.7 CONTEXTUAL APPLICATION DEFINITION

Definition to operational application of the system was defined as a pre-cursor to an invasion:

Purpose: remove soft targets from the building and disable unprotected hardware leaving the main structure of the facility intact and potentially sensitive content

An analogy scenario: a strategic pre cursor strike to an aforementioned airport terminal prior to its acquisition by appropriate forces enabling a forward control to be erected in a hostile country or acquisition of sensitive material or data from a defence establishment; following air strikes the outer building would be devoid of credible defence allowing forces intervention for seizure/ recovery of sensitive material without being compromised.

2 REQUIREMENTS

Customer requirements; usually substantially more in depth than stated in 1.4 retain a sense of ambiguity and are often based on assumptions. Requirements are split into requirement groups: design requirements; stem from the customer brief and are the primary function of the system; functional requirements; enabling actual function of the system i.e. propulsion system et.al. material requirement; suitable material application. [2]

Each highlighted requirement must be fully assessed, and option studies excised the only part of the request not surrounded by ambiguity is the need for a blast/ fragmentation type payload and so will be the subject of 2.5 to enable overview of process type to be excised in the delivery from requirement to concept. [2]

2.1 DESIGN REQUIREMENTS

Design requirements stem directly from the customer requirement and focus on the intended use and function of the device e.g. blast fragmentation and aircraft compatibility being the only stipulated design requirements. Emphasis should be given to inferred requirements not specifically mentioned within the brief; they will be guided by parameters such as legislation, operational requirements, lifecycle constraints, among others. [2]

Design requirements for such a system could be but not limited to:

Blast function	Safety
Fragmentation	Storage
Compatibility with airframe	Transport
Navigation	Operational range /flight time
Guidance	Cost
Targeting to a tolerance	Reliability
Lightweight	Communication

2.2 FUNCTIONAL REQUIREMENT

Functional requirements are items not often highlighted by the customer that were expected to be implemented without being mentioned. Functional requirements can be a derivation of design

requirement but are the unspecified parts of the device that require significant investment to allow intended function. [2]

Functional requirements for such a system could be but not limited to:

Propulsion system	Lifecycle consideration
Steering system	Assembly/disassembly/Maintenance ease and cost
Mass equal to or less than relative payload	Threat assessed and mitigated
Geometric constraints	Atmospheric operation
All weather operational capability	Minimal environmental impact on function or disposal
Radar avoidance	Low carbon footprint for manufacturing

2.3 MATERIAL REQUIREMENT

Materials of the assembly vary throughout the system; metals, composites and plastics to primary explosives, boosters and detonators. Material requirements can be honed into a generic concept, each consideration should be assessed as through life to detonation/disposal:[2]

Commercially	Be sustainably available and easy to source. Material for manufacture should be of low cost.
Environmentally	Have little to no impact on its environment. Where possible have zero or low toxicity. Material sourcing manufacturing and disposal should have a minimalist carbon footprint.
Chemically	Sustainably available fully endorsed and a stable compound with appropriate activation energy for its purpose in the system.
Processing	Safe to process – the processing involved in taking raw material to a complete operational weapons system through concept to disposal or function within an operational arena is fraught with a high level of risk and substantial amount of hazard, material must remain safe during machining, assembly, manufacture, transport operation and disposal. The as low as reasonably practical approach should be adopted in all aspects of delivery of a system lifecycle.
Function	Function of the system should be seamless; operation should only happen how it is intended and when intended, appropriate material should be ascertained to deliver these system functions.
Weight	Application to an airframe requires weight limitation to be at the forefront of any design or concept.
Storage	Safe to store - Enduring - Resistant to ageing and corrosion.

Appropriate materials research and development should be undertaken inclusive of material testing and trials to enable implementation that is aptly suited to its role or function within the system albeit; metal framework, explosives or retaining mechanisms such as bolts and adhesive.

2.4 CONSEQUENCE OF NOT MEETING REQUIREMENT

Consequence of not meeting requirement varies somewhat depending on the requirement importance; if a requirement for a blast fragmentation warhead is surpassed and an Alternate warhead is placed that does not achieve the contextual application listed in 1.7. e.g. a shaped charge that will condemn the structure; it no longer serves the required purpose in the arena and will not be used. This alludes to extra logistical costs and delays of providing a forward command structure in a hostile combat zone as well as the human cost. For the most part failure to meet a requirement will likely render the system obsolete unless such a requirement is an additional grandeur requirement subjectively assumed by the designer; however, these types of requirement are often quashed at design proposal due to their associated cost deemed unjustified. As consequence of a missed or unmet requirement will likely result in cancellation of a program and unit sales if caught at a commercial level prior to manufacture. Should the system make it into service the cost becomes far greater and will likely result in a human cost. [2]

2.5 REQUIREMENTS TO CONCEPT

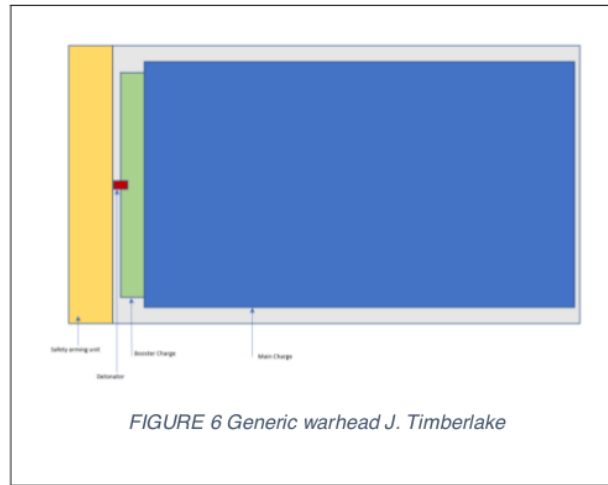
Full delivery of each requirement to concept would be unobtainable within the remit of this document so focus remained on the payload module and its associated requirements. Several methodologies exist to transition from requirement to concept the example used herein for an outlined example is a **minimalist** Quality function deployment (QFD) for the planning stage to establish design requirements and the rationale behind decisions made. [2, 7]

			Design requirements					
			+ Amount of explosive	+ brisance of explosive	+ Velocity of detonation	+ brittleness of casing	+ weight of module	+ GPS sensors
Customer requirement and importance rating	10	Blast	*	*	*	+	+	
	10	Fragmentation	+	*	*	*	*	
	10	Aircraft fitment	-			-	#	
	10	Building target	*	+		+	+	*

Following QFD, requirements should be assessed against materials, manufacture and assembly to ascertain suitability of the solution against capability. Each stage should be subjected to failure modes & effect analysis to ascertain risk that may be presented throughout the lifecycle. Any major or safety relative failures should be addressed with root cause analysis and modifications where appropriate. [2, 7]

For this example, minimalist requirements have been assessed to enable delivery of the document, it is vital to refer to 1.7 when considering this stage.

a generic warhead will contain Safety arming unit, detonator and booster [2].



Effect requirement should be explored, and definition considered when assessing required output [2, 7];

In reference to 1.7. explosives content should enable fragmentation yet refrain from structural damage. The working volume wherein the munition will deliver the desired effects will also define the required tolerance for the systems targeting and GPS capability. [7].

Fragmentation: significantly sized in order to remove soft targets but not so insignificant that remnant cladding will prevent delivery of such an effect. The application of fragmentation retains a myriad of variables; fragment size, direction, distribution, mass, velocity et.al. This instance refrained from natural fragmentation; fragment size was defined by a machined casing much like a grenade, this served to provide a quantifiable fragment size output, only deviating upon ballistic contact with solid material. Fragment mass was a simple engineering application that material density would define over the machined fragment volume. Denser fragments of the same mass will be smaller volumetrically, providing better penetrative qualities: the same mass loading will be applied over a smaller contact surface area increasing likelihood of failure of the target material. [2, 9, 10]

Fragment velocity distribution and direction could be calculated from a collation of Gurney and Taylor equations: [8]

This means that Equation (10) becomes:

$$CE * 1 / (L/R + 1) + CE * 1 / (1 + R/L) = \left(\frac{2M_1}{2} + \frac{1}{2} \frac{C}{2} \right) V_1^2 + \left(\frac{M}{2} \left(\frac{8+4n+3n^2}{15} \right) + \frac{1}{2} \frac{C}{2} \left(\frac{8+4n+3n^2}{15} \right) \right) G^2 \quad (13)$$

This equation now contains two distinct parts. On the left-hand side of the equation, energy in the X direction and energy in the YZ (or r) direction respectively and on the right-hand side, energy in the X direction and energy in the YZ (or r) direction respectively.

This means Equation (13) can be represented as:

$$\frac{CE}{1+R/L} = \left(\frac{M}{2} \left(\frac{8+4n+3n^2}{15} \right) V_1 + \frac{1}{2} \frac{C}{2} \left(\frac{8+4n+3n^2}{15} \right) \right) G^2 \quad (14)$$

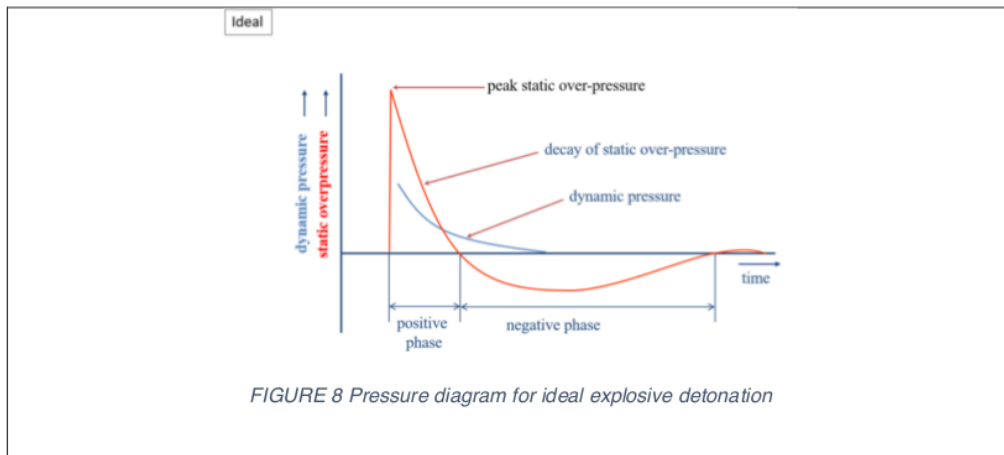
For the cylindrical part of the casing ("in the r direction") and as:

$$\frac{CE}{L/R+1} = \left(\frac{2M_1}{2} + \frac{1}{2} \frac{C}{2} \right) V_1^2 \quad (15)$$

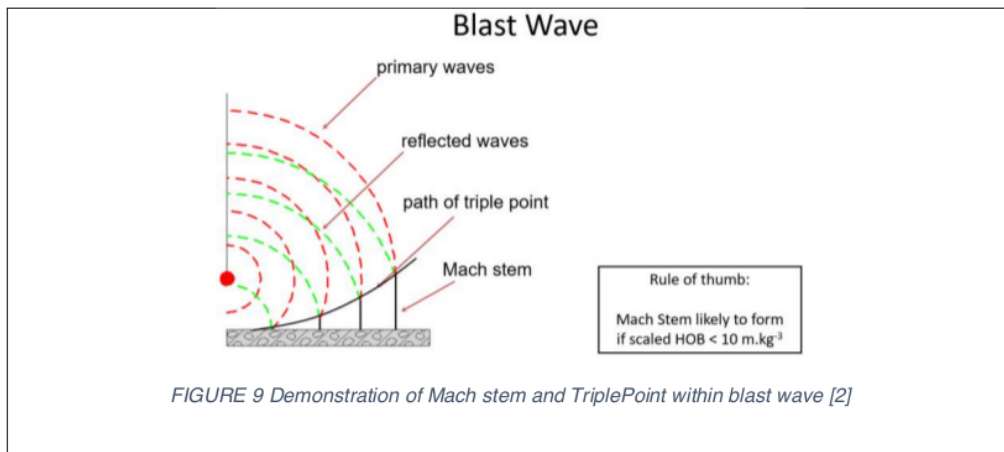
For the end plates ("in the X direction").

FIGURE 7 Real time calculation of fragment velocity for cylindrical warheads [8]

Blast: To shatter glass/dislodge cladding but not to damage the buildings structural integrity. Blast damage is realised by introduction of peak static overpressure in the form of a blast wave created by the detonation and relative sublimation of the main charge. Static overpressure degrades and dynamic pressure from the respective sublimation is introduced. As static overpressure degrades to zero and dynamic pressure is reducing, the mass expanse of air will retract causing a negative phase of the static over pressure. The target material; glass, requires 1 PSIg of overpressure to shatter and between 1 PSIg and 2 PSIg for failure of the respective cladding. The structural integrity of the steel framed building however becomes compromised at around 3PSIg; requiring a measured approach to the systems delivery. The target materials aid in fragmentation causing broken glass and other projectiles to form following the initial shock to the building often referred to as a tertiary effect of the explosive. [2,11,12, 13.]



Blast pressure and brisance (shattering effect) to disrupt the casing to failure will be the leading element but application of the warhead should be defined to enable effective delivery. To enable correct function an airburst may be best; to attain distance of application Hopkinson scaling laws should be applied and consideration should be applied to the shock front (Rankine-Hugoniot) and reflected blast waves creating a Mach stem. [2,9,13,14.]



Blast pressure can be calculated. [15]

Kinney [3] presents a formulation that is based on chemical type explosions. It is described by Equation (8) and has been used extensively for computer calculation purposes,

$$P_{zo} = P_o \frac{808 \left[1 + \left(\frac{Z}{4.5} \right)^2 \right]}{\left\{ \left[1 + \left(\frac{Z}{0.048} \right)^2 \right] \left[1 + \left(\frac{Z}{0.32} \right)^2 \right] \left[1 + \left(\frac{Z}{1.35} \right)^2 \right] \right\}^{0.5}} \quad (8)$$

where Z ($\text{m/kg}^{1/3}$) is the scaled distance, Equation (4), and P_o is the ambient pressure.

FIGURE 10 Blast pressure formula [15]

The primary constituent of providing blast capability is the initiation and subsequent detonation of an initiation train culminating in the yield from an appropriately large mass secondary explosive such as composition B or HMX. [2, 9.]

3 CONCEPTUAL DESIGN PROPOSAL

The weapons system requirement culminates the delivery of a complex system; operational on several platforms. Modular approach was implemented as is common practice in modern engineering; this approach allows for contracted manufacturing and support, retention in service should a fault occur, graduated systemic upgrade (each subsystem can be engineered to a new revision over time and slowly integrated once configured to spread cost and 'fleet downtime'). [16, 17, 18]

The missile was the predominant focus of this section however brief mention was given to the interface unit in 3.1.

3.1 INTERFACE AND LAUNCH PLATFORM

The platform is an integral part of the operational system; it provides standardised mounting and release mechanisms, housing for interface units that allow the delivery platform to access targeting/firing mechanisms. It requires minimal modification to the platform and retains agility to be adapted to other applications with only minimal modification in the form of mechanical mounting, additional electronic hardware and required software.

Component /module /assembly	Method of Function	Material properties	Potential failure mechanism(s)	Failure mitigation
Platform framework	Supporting framework to enable standardised mounting of missiles and supporting interface hardware listed in this table.	Lightweight, High material strength, cyclic strength, corrosion resistance.	Fatigue, corrosion, impact.	Regular inspection (NDT), matrix structure, coating.
Relevant aircraft mounting adapter plate	A plate to mate a standardised launch platform to a menagerie of different airframes.	Lightweight, High material strength, cyclic strength, corrosion resistance.	Fatigue, corrosion, fittings.	Regular inspection (NDT), coating, maintenance.
Platform framework housing	An aerodynamic shaped and formed housing to encapsulate assembly content of the launch platform to provide	Lightweight, High material strength, cyclic strength, corrosion resistance.	Fittings, composite 'tear', Abrasion.	Coating, regular inspection, maintenance.

	mitigation against elements.			
Umbilical mount to aircraft	The main electronic 'hook up' to the aircraft to allow connection of all mentioned hardware to become integrated into the cockpit.	Lightweight, High material strength corrosion resistance.	Corrosion, Damage from poor fitment/ removal, Fatigue.	Coated and IP rated, regular inspection.
Electronic interface hardware (translator for the aircraft and send/receive unit)	A self-contained computer that will manage data transfer between the aircraft and missiles receiving relevant information to enable target to be engaged as well as allowing the pilot to remain informed about the progress of the missile delivery as well as a GPS function and locator should jettison occur.	Lightweight, Small, High processor speed, Corrosion resistant,	Corrosion and shorting from weather ingress.	Coated and IP rated Regular inspection and function tested.
Missile umbilical	The main electronic link to the missile prior to launching it will allow data to be transferred to the on-board computer regarding target and trajectory information.	Lightweight, High material strength, corrosion resistance.	Corrosion Damage from poor fitment/ removal, Fatigue.	Coated and IP rated, regular inspection.
Missile mechanical mounting	A standardised mounting mechanism that allows only one variant to be made of the missile for multiple applications.	Lightweight, High material strength, cyclic strength, corrosion resistance.	Fatigue, corrosion, fittings.	Regular inspection (NDT), coating.

3.2 MISSILE

the missile is sectioned into section types; each containing modules. Given the delivery platform has been specified (airframe mounted) and the target is a building the missile type that was selected was a cruise type missile. This was rationalised due to radar tracking avoidance requirement to avoid countermeasures; a generic cruise missile will retain a very low altitude flight path until a 'final approach' distance has been achieved wherein it will position itself into the most suitable angle of attack.

3.2.1 Chassis and Fairings

Component /module /assembly	Method of Function	Material properties	Potential failure mechanism(s)	Failure mitigation
Airframe	Rigid framework that all modules, fairing panels and wiring will attach with integrated mounting for standardised missile mounting	Lightweight, High strength material properties (rigid) cyclic strength, corrosion resistance	Fatigue, corrosion, impact .	Regular inspection (NDT), matrix structure, coating.
Standardised missile mounting	Billet machined mounting that provides standard	Lightweight,	Fatigue, corrosion,	Regular inspection (NDT),

	"consumable" type mounting to mate the missile to its launching platform	High strength material properties (rigid) cyclic strength, corrosion resistance	impact, wear abrasion.	periodic replacement, coating.
Nosecone fairing	Ogival shaped fairing at the fore of the missile used to deflect aerothermal flow and provide ingress protection	Lightweight, High strength material properties (rigid) cyclic strength, corrosion resistance abrasion resistance heat resistance/dissipation		
Fairing panels	Missile housing fairing panels with variable access points for relevant areas			
Control surface fairing	Aileron type fins that allow the missile to steer			
Sustainer exhaust shroud fairing	Shroud type fairing to cover the exhaust and prevent turbulent flow impeding the function of the sustainer motor			
Sustainer intake shroud fairing	Shroud type fairing to allow the missiles sustainer motor to scoop air into the intake unimpeded in a laminar fashion			

3.2.2 Propulsion

Component /module /assembly	Method of Function	Material properties	Potential failure mechanism(s)	Failure mitigation
Solid fuel booster motor assembly	Initiator begins deflagration of triple based propellant and delay timer fuse to produce initial thrust following separation from the airframe and begin the countdown to separation by	casing and mountings Lightweight appropriate brittle propellant, 'breakup charge' initiator and pyrotechnic bolts.	casing and mountings mechanical failure due to manufacture or loading/handling, insult propellant, 'breakup charge'	casing and mountings NDT testing, visual inspection routine maintenance propellant, 'breakup charge'

	way of pyrotechnic bolts, application of the boost motor allows a minimum safe flight time and ideal 'start up for the ram jet engine'. Following separation, a small charge will detonate to break up the boost motor into small negligible pieces	Reliability Appropriate reactivity	initiator and pyrotechnic bolts. Chemical decomposition Insult, atmospheric ingress.	initiator and pyrotechnic bolts. Lifecycle implementation, inspection, periodic in-service sample/batch function testing
Ram jet sustainer motor and fuel injection system	Following separation of the booster motor ramjet will initiate and provide propulsion to the target	Lightweight, reliable, corrosion resistant Heat resistant Mechanical resistance to cyclic loading high peak stress loading	Mechanical failure Hydraulic/fluid failure Heat failure Explosion	Adequate mechanical testing for fatigue and force distribution under thrust Adequate material selection to resist temperature range
Fuel tank and pumps	To provide ramjet motor with adequate fuelling to run sustainer motor	Lightweight Strong material	Heat failure Pressure failure Leak mechanical failure	Additional shielding within the module to prevent induction of heat Pressure test and inspect tank on routine maintenance

3.2.3 Payload

Component /module /assembly	Method of Function	Material properties	Potential failure mechanism(s)	Failure mitigation
SAU	To provide a control measure to prevent premature initiation of the warhead during non-operational procedures and provide a safe and secure way of allowing initiation either at a predetermined distance from the	Lightweight Good conductor/insulator where appropriate RF/X-ray shielded	Electrical failure Rf/x-ray interference Short	Automated testing against interference and relevant continuity /insulator /resistance testing

	delivery platform or on a timed mechanical/electrical /chemical circuit, this will allow operation of the laser proximity fuze. Ability to be made safe following arming without the weapon detonating i.e. after maximum flight to target time Required testing function mode for missile maintenance			
Warhead including Detonator booster main charge (secondary High Explosive)	To provide a functioning bomb at the required delivery point, that will function as required when required to withstand an acceptable level of insult without detonation	Lightweight Brittle, dense casing Homogeneous filling and forming of explosives Reliable function	Chemical decomposition Insult, atmospheric ingress.	Lifecycle implementation, inspection, periodic in service sample/batch function testing

3.2.4 Power

Component/module	Method of Function	Material properties	Potential failure mechanism(s)	Failure mitigation
Battery 1	Bus 1 constant loading	Lightweight Capable of producing required voltage Capability to be activated when in an operational capacity but not able to degrade whilst in store	Battery degradation, Early/accidental activation, battery failure	Battery inspection testing at routine maintenance. Link battery activation into unique launch command sequence, arrange batteries so bus 1 and 2 can share load as a 'fall back' mechanism.
Battery 2	Bus 2 Variable load			
Battery 3	Bus 3 Capacitor charging			

3.2.5 Electronics Hardware

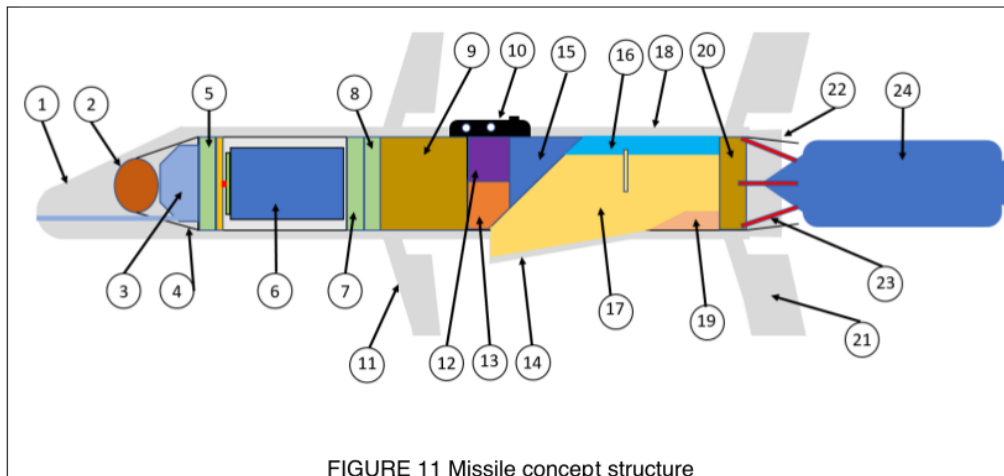
Component /module /assembly	Method of Function	Material properties	Potential failure mechanism(s)	Failure mitigation
Guidance system	Global positioning and missile route planning works in conjunction with the auto pilot system and communications receiver to provide an	Lightweight Good conductor/insulator where appropriate RF/X-ray shielded	Electrical failure Rf/x-ray interference Short	Automated testing against interference and relevant continuity /insulator /resistance testing

	Indirect approach method in order to mislead its trackers into what its intended target would be			
Telemetry system	Records dynamic information from various sensors and relays it to the auto pilot system in a closed loop to enable any adjustments that may be required and in addition to dispatching the information to the aircraft			
Autopilot	Amasses and collates information from guidance, telemetry and communications receiver and calculates relative adjustment to be sent to the Control surface motor regulator unit			
Control surface motor regulator unit	Receives commands from the autopilot to input power to control surface motors at a time for a certain duration to achieve trajectory change in conjunction to attaining motor positioning to enable feedback to the autopilot system			
Control surface motors	Receive a command to rotate to a specified point and send confirmation of what they have achieved			
Targeting system including seeker	Provides positive identification			

and laser proximity sensor	using the video seeker that its target has been acquired within final approach it will engage with the auto pilot to enable trajectory control the laser proximity sensor will activate and when the target is aligned at a specified distance it will trigger the SAU to initiate the device			
Communication receiver system	Communications receiver will collect information from the aircraft and distribute it within the missile electronic system			
Communication dispatch system	Will provide the aircraft with a log of all recordable information associated with the operation of the missile			

3.3 Arrangement and Module Listing

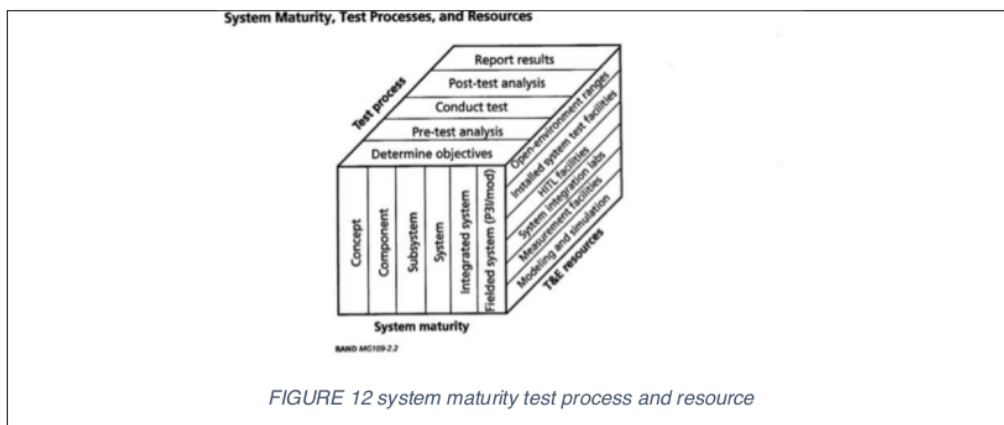
Fig 11 shows the conceptual arrangement within the missile assembly and denotes the module number the following table highlights the module number against its description



No.	Module	No.	Module
1	Nosecone	13	Control surface motor regulator unit
2	Seeker	14	Intake shroud
3	Targeting system including laser proximity sensor	15	Guidance system assembly
4	Airframe	16	Fuel tank and pump assembly
5	Bus 3 battery	17	Ram jet sustainer motor assembly and fuel injection system
6	Warhead assembly	18	Fairing panels
7	Bus 2 battery	19	Communication dispatch system
8	Bus 1 battery	20	AFT control surface motors
9	Telemetry, auto pilot, FWD control surface motors	21	Control surface fairing AFT
10	Universal mounting and umbilical mount	22	Exhaust shroud
11	Control surface fairing forward	23	Pyrotechnic booster motor mounting
12	Communications receiver	24	Booster motor assembly including motor SAU and fragmenting disposal charge

4 DESIGN TESTING

Underwriting safety, function, reliability, and environmental elements of a system are covered through standards implemented by NATO and governments. For the majority STANAG testing, Air STD testing and MIL STD testing provide guidance on application (e.g. STANAG 4325: 2002 and AAP-48: 2013). 4.1. covers a selection of tests implemented in the delivery. All levels (component/assembly system) must be tested at all stages (CADMID/T). reflection should be taken from requirement to determine objective. [1, 2, 9, 19, 20]



4.1 OVERVIEW TESTING

4.1.1 Standard Testing of Components and Materials

Sub assembly/component testing	Material testing
NDT mechanical testing (flex/stress/strain) drop test fatigue testing fixing and fastener testing electrical resistance coating tests (where applicable) aerothermal testing abrasion and impact testing insult and threat analysis testing (survivability) hardness testing thermal testing environmental testing FEA modelling simulation modelling	Mechanical testing Electrical testing Corrosion assessment Aerothermal testing Hardness testing Material analysis Thermal testing FEA modelling Chemical compatibility testing

4.1.2 Chassis and fairings

Component /module /assembly	Sub assembly/component testing *
Airframe	aerothermal testing
Nosecone	aerodynamic testing
Fairing panels	launch and carriage compatibility
Control surface fairing	load testing
Sustainer intake shroud	launcher release retention testing
Sustainer exhaust shroud	

4.1.3 Propulsion

Component /module /assembly	Sub assembly/component testing*
Solid fuel booster motor assembly	cook off test (deflagration to detonation) function testing thrust testing safe separation testing sled testing motor SAU testing
Ram jet Sustainer motor and fuel injection system	Sled test function testing thrust testing hydraulic testing
Fuel tank	function testing pressure testing

4.1.4 Payload

Component /module /assembly	Sub assembly/component testing*	Material testing*
SAU	Function test Anti-tamper test Rf /x-ray testing	
Warhead including Detonator booster	Initiation train testing Function testing	Qualative and quantitative chemical analysis Rotter testing (figure of insensitive)

main charge (2 nd HE)	Soft and hard capture fragment testing Pressure output testing	Shock initiation properties POP plot Bam friction Cylinder/rate stick testing for Velocity of detonation CT scanning for porosity Detonator reliability /timing tests Any other relevant High explosive properties investigations
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4.1.5 Power

Component /module /assembly	Sub assembly/component testing
Battery 1	Voltage testing
Battery 2	Switch testing
Battery 3	Load testing

4.1.6 Electronics Hardware

Component /module /assembly	Sub assembly/component testing*
Guidance system	Function test
Telemetry system	Anti-tamper test
Autopilot	Rf /x-ray testing
Control surface motor regulator unit	
Control surface motors	
Targeting system	
Communication receiver system	
Communication dispatch system	

*If not included within the standard testing

4.2 MODULE TESTING

The module requires testing to ensure its function meets requirement, testing should be arranged in an automated test rig (inert missile with removable modules to test functionality; the payload and propulsion units will have to be suitably assessed in a simulant scenario).

4.3 SYSTEM TESTING

The system as an entity must be tested to ensure operation of modules in synchronisation to enable operation of the system to deliver effect. Testing may include but not limited to:

Sled test	Airframe compatibility trials
Accuracy trials	Operational trials
Guidance trials	Flight trials
Stability testing	Live trials
Considerations: Each test should be relevant to a requirement to assess system suitability in that it will meet its design and functional requirement: each pre-test analysis will identify further hazards to be assessed such as with storage and handling constraints	

5 USER INTERFACE

Human factors remain a challenging part of munition integration (post procurement operation due to weight, size and hazardous content). Measures should be implemented to control handling and storage of systems to mitigate any non-conformance in operation.

5.1 STORAGE AND TRANSPORT

missiles shall remain in dedicated container until such a time it is required for maintenance or operation

Container System

The container is modular and comprised of assemblies to create a safe stowage for the missile [21, 22,23,24.]

Component	Method of function	Considerations
Top cover	Rigid metal top cover plate that is affixed to the base plate retaining an air tight seal can interface with weapons loading equipment forklift and crane	Operational storage environmental considerations should define container capabilities; combat arenas can vary from desert to arctic conditions depending on adversary so the range of temperature and humidity should be considered there isnt always a temperature and humidity controlled store for explosives. All containers are subject to rigorous testing against NATO defined standards eg AEPP-3 : 2015, AEPP-1 : 2001 STANAG 2828 STANAG 4280
Stowage adaptor assembly	Modular insert that is bolted to the base plate and retains the missile in place with removable rings can interface with weapons loading equipment handling dolly forklift and crane	
Base	Rigid metal base plate that attaches to the top plate can interface with weapons loading equipment forklift and crane	





FIGURE 14 storm shadow alternate container top removal

5.2 HANDLING

System handling should be exercised by competent and suitably qualified and experienced personnel. Training should be given to the operation of any manual handling equipment used during the movement of any High explosive.

Handling scenario	Method of handling	Considerations
Airfield/aircraft carrier deck	Stowage adaptor assembly affixes to general handling dolly	With all operations involving munition SQEP and competent persons work to Work instructions following Technical Instruction to Armament Depot (TIAD)/ Air publication (AP)
Maintenance workshop general movement	Stowage adaptor assembly affixes to movement dolly	
Maintenance workshop – maintenance activities	Requires removal from stowage adaptor assembly affixes to maintenance assembly stand	
Maintenance workshop – stand transfer	Removal of ring segment transfer to maintenance stand with overhead gantry crane and configured lifting equipment	

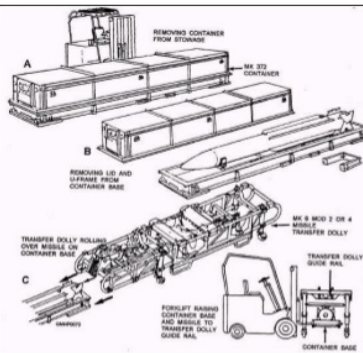


FIGURE 15 Simulant of conceptual container system



FIGURE 16 airfield/ maintenance general handling missile handling dolly



FIGURE 17 Operational missile assembly stand

6 DISCUSSION

6.1 SYSTEMS ENGINEERING

Operations involving introduction of a system require a systemic and analytical approach to meet a set of requirements. Each lifecycle stage should be assessed at each staged gate to ensure safe delivery of the system.

6.2 STANDARDS, QUALITY ASSURANCE AND ENVIRONMENT

During the lifecycle; requirements of the system must benchmark against relevant standards to ensure quality is delivered without unforeseen non-conformance and consideration to environmental output of systems (e.g. MIL HDBK 1670: 0 - ENVIRONMENTAL CRITERIA AND GUIDELINES FOR AIR-LAUNCHED WEAPONS) and for Carbon zero manufacture. [2, 25.]

7 CONCLUSION

Introduction of weapons systems require systemic requirement capture, this should have a lifecycle approach considering aspects of delivery, capability, environmental and commercial impact. Each customer requires standards to be met for delivery: in the 'west' this will likely be defined by a coalition of NATO approved standards.

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FIG 1	A general view of the newly built terminal of Pyongyang International Airport. https://www.scmp.com/news/asia/east-asia/article/1831620/inside-north-koreas-shiny-new-international-airport-where-are
FIG 2	internal view of Pyongyang International Airport terminal. https://www.scmp.com/news/asia/east-asia/article/1831620/inside-north-koreas-shiny-new-international-airport-where-are
FIG 3	Example of vulnerable target contained in the terminal https://www.welt.de/reise/gallery143486765/Neuer-Airport-soll-mehr-Touristen-ins-Land-locken.html
FIG 4	F35 lightning IIB https://airrace.org/news/f-35-announcement/
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FINAL GRADE

GENERAL COMMENTS

Instructor

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GRADING FORM: SMU GENERIC_GJ

JORDAN
TIMBERLAKE

47.30

RESEARCH-INFORMED LITERATURE



Excellent engagement with literature including technical, explosive, regulatory and target analysis publications

7

KNOWLEDGE AND UNDERSTANDING



"I'm not sure at the end of the paper whether I fully understand what the design is, what it's filled with and how it functions. We have a comprehensive list of tests that the munition should undergo and we understand what good looks like. But the design

12

piece is weak. The gurney equation is quoted but how does that reflect in the design. How are you going to use the information?"

ANALYSIS



"Evidence of some logical, analytical thinking and synthesis. Can analyse new and/or abstract data and situations without guidance. An emerging awareness of different stances and ability to use evidence to support the argument. There is an understanding the requirements are complex and come from different sources but the potential interactions and influences are not clearly mapped. Some of the systems engineering looks a little odd to me."

13.8

PRACTICAL APPLICATION AND DEP.



Some of the systems engineering looks a little odd to me. However recognition that we are dealing with a complex article and there are many viewpoints is recognised.

10

SKILLS FOR PROFESSIONAL PRAC.



the writing style is a little awkward. I'd like to see plainer English used.

4.5