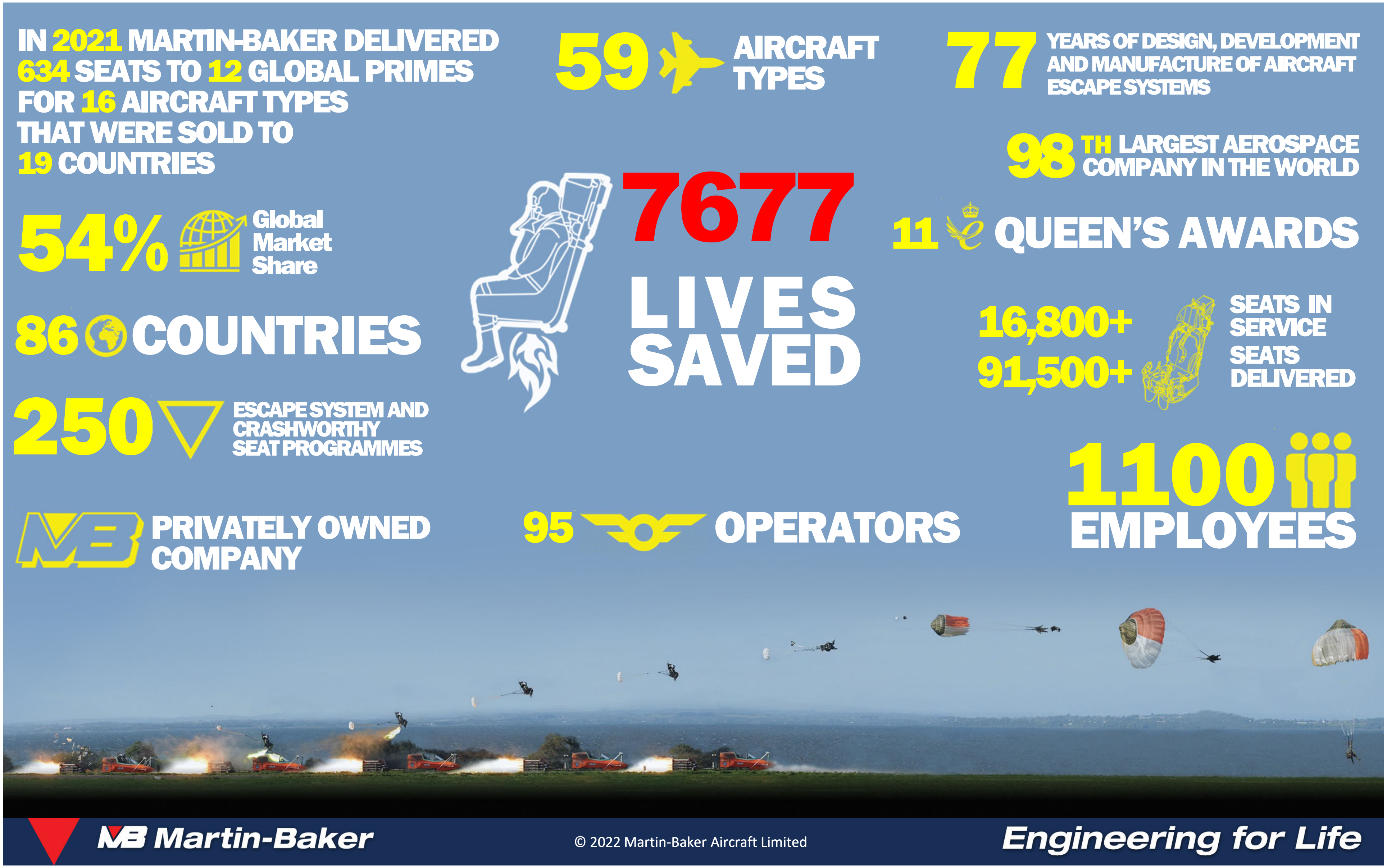
The Role of a Systems Engineer at MBA

CAD/PAD Technical Exchange Workshop

12 - 14 July 2022

Contents


IN 2021 MARTIN-BAKER DELIVERED
634 SEATS TO 12 GLOBAL PRIMES
FOR 16 AIRCRAFT TYPES
THAT WERE SOLD TO
19 COUNTRIES
59 AIRCRAFT TYPES
77 YEARS OF DESIGN, DEVELOPMENT AND MANUFACTURE OF AIRCRAFT ESCAPE SYSTEMS
98 TH LARGEST AEROSPACE COMPANY IN THE WORLD
54% Global Market Share
7677 LIVES SAVED
11 QUEEN'S AWARDS
86 COUNTRIES
16,800+ SEATS IN SERVICE
91,500+ SEATS DELIVERED
250 ESCAPE SYSTEM AND CRASHWORTHY SEAT PROGRAMMES
1100 EMPLOYEES
PRIVATELY OWNED COMPANY
95 OPERATORS
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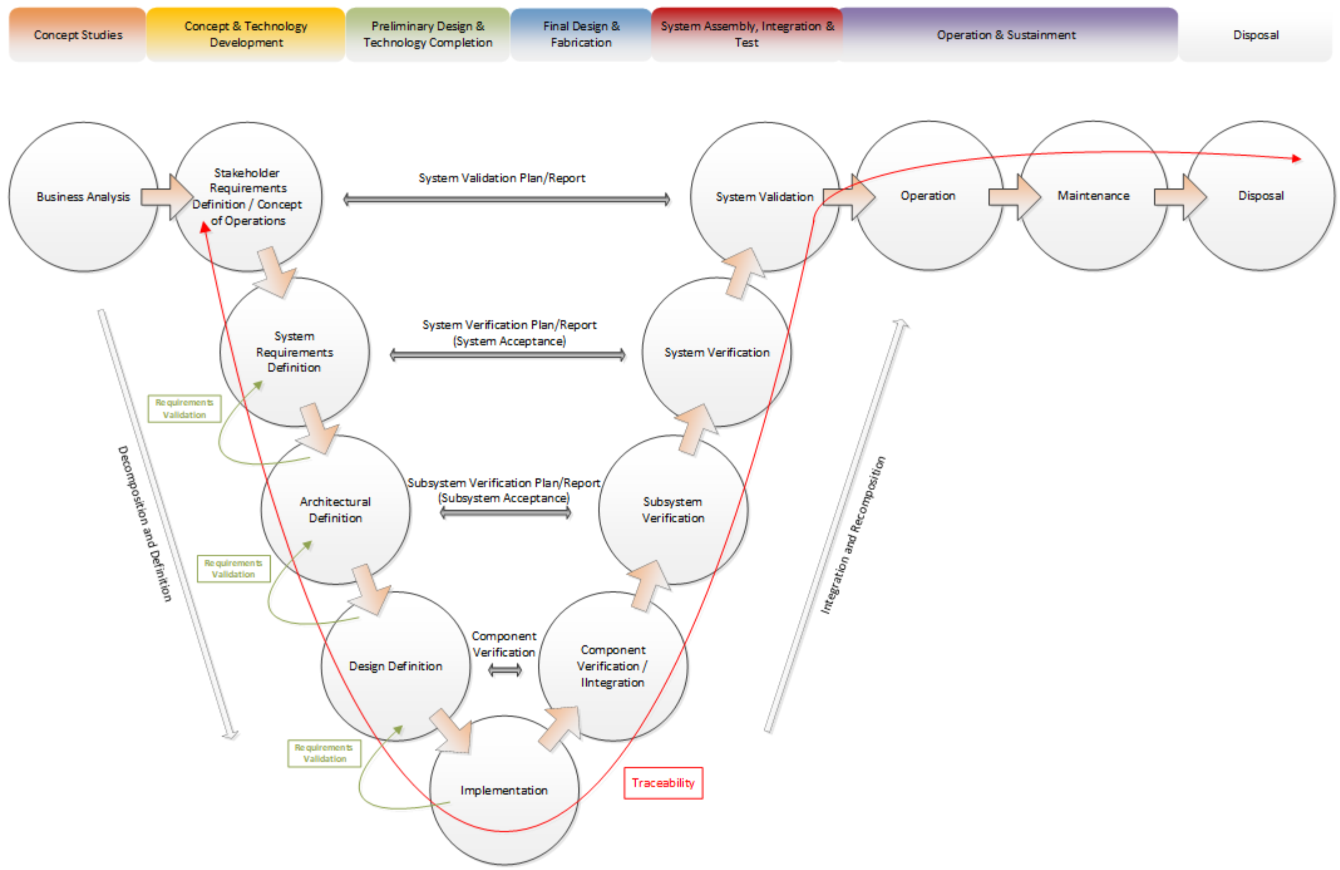
Engineering for Life

Systems Engineering Process

- MBA utilise traditional systems engineering 'V-Model'
  - Programme are tailored to ISO/IEC/IEEE 15288:2015



Model Based Systems Engineering

- MBSE allows us to capture decisions, justifications and provide traceability throughout the life cycle of a product in a centralised, logical way
- System models can be used to directly interface across functions and provide a single source of truth
- Customers, suppliers and regulators are accustomed to documents for decisions, justifications and evidence, not models
- MBA adopted a model based systems engineering approach around 10 years ago
  - We are currently a stage 3 organisation: Model-Enhanced
  - Practice MBSE in Sparx Systems Enterprise Architect (EA)

Stage 1: Document-Based

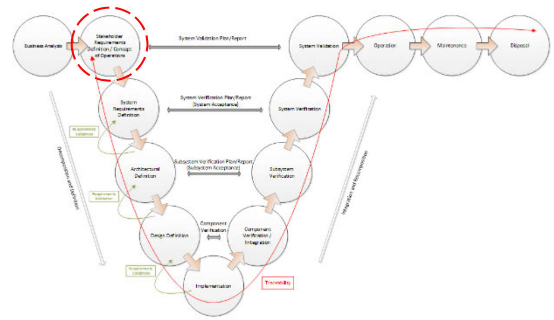
Stage 2: Document-Centric

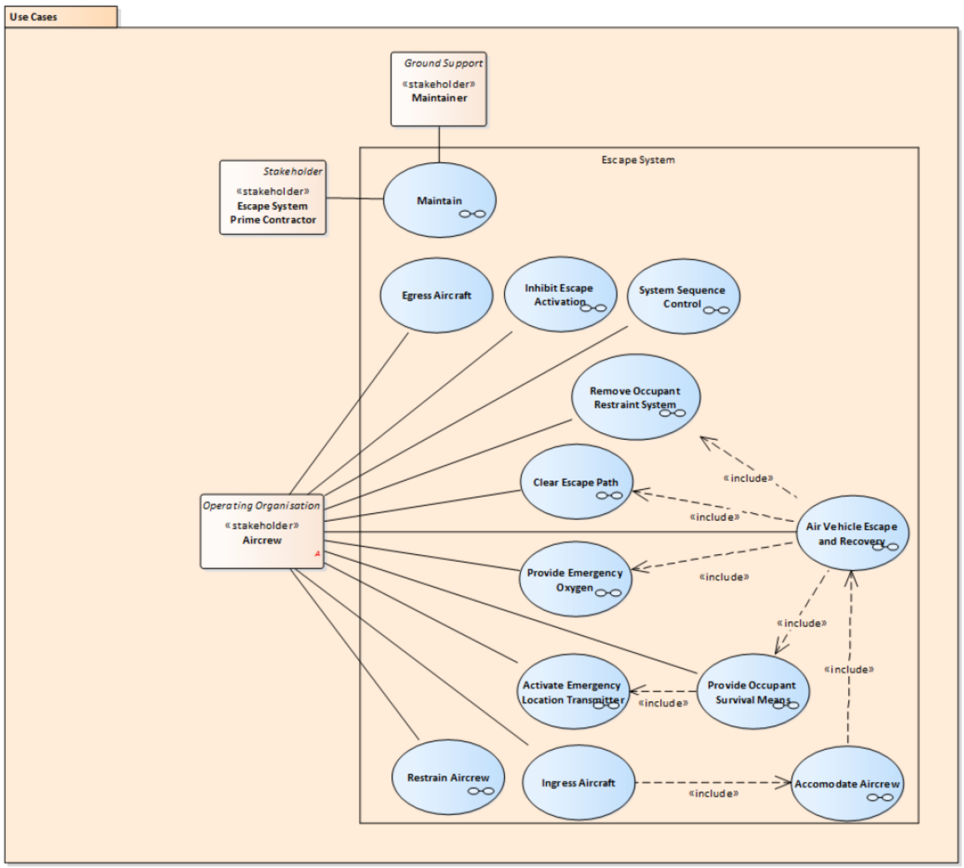
Stage 3: Model-Enhanced

Stage 4: Model-Centric

Stage 5: Model-Based

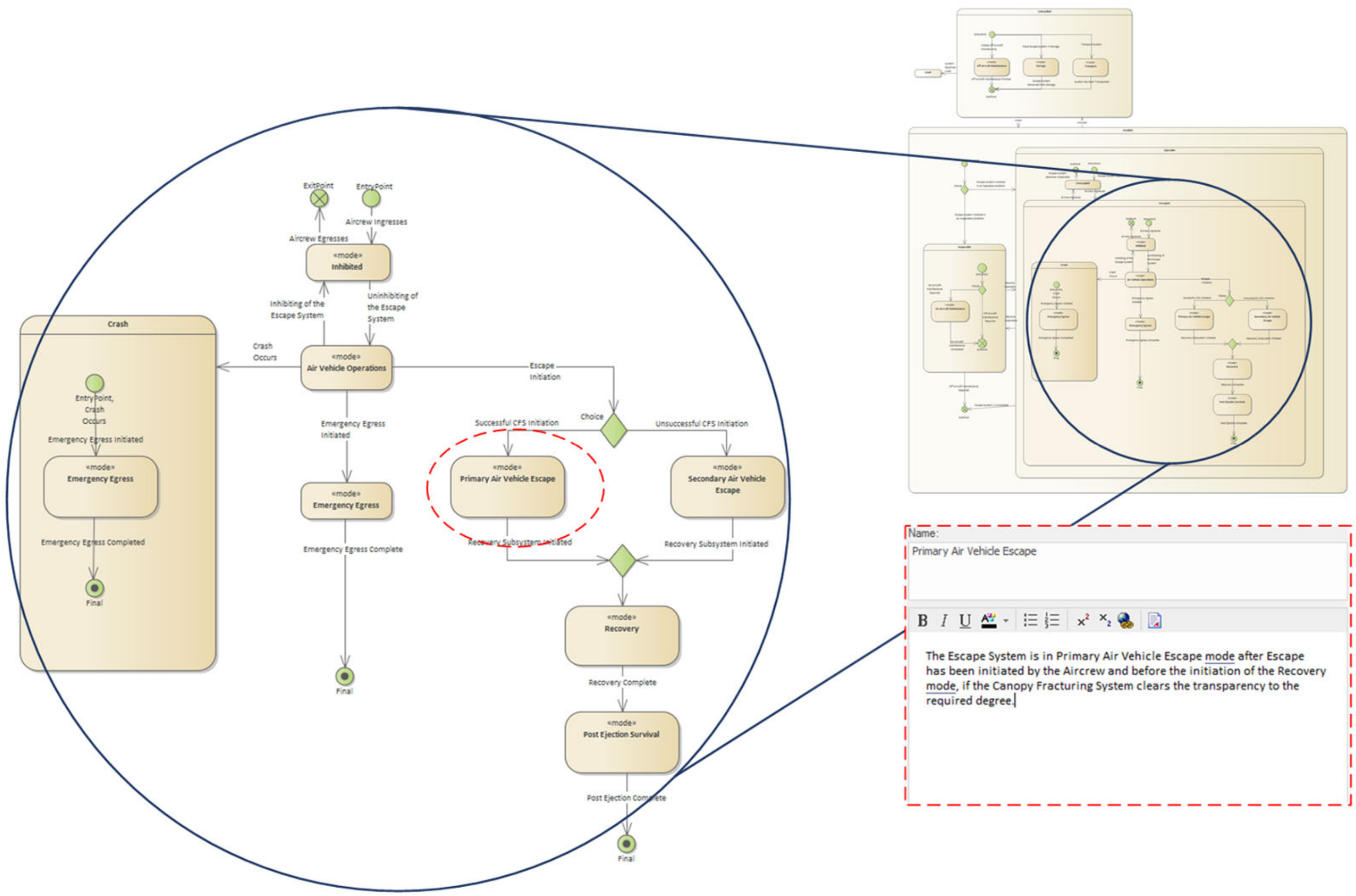
Decomposition & Definition I





- Model System stakeholders
- Model use-cases for System context and requirement derivation
- Can be extended to activity, sequence and states and modes

Decomposition & Definition II



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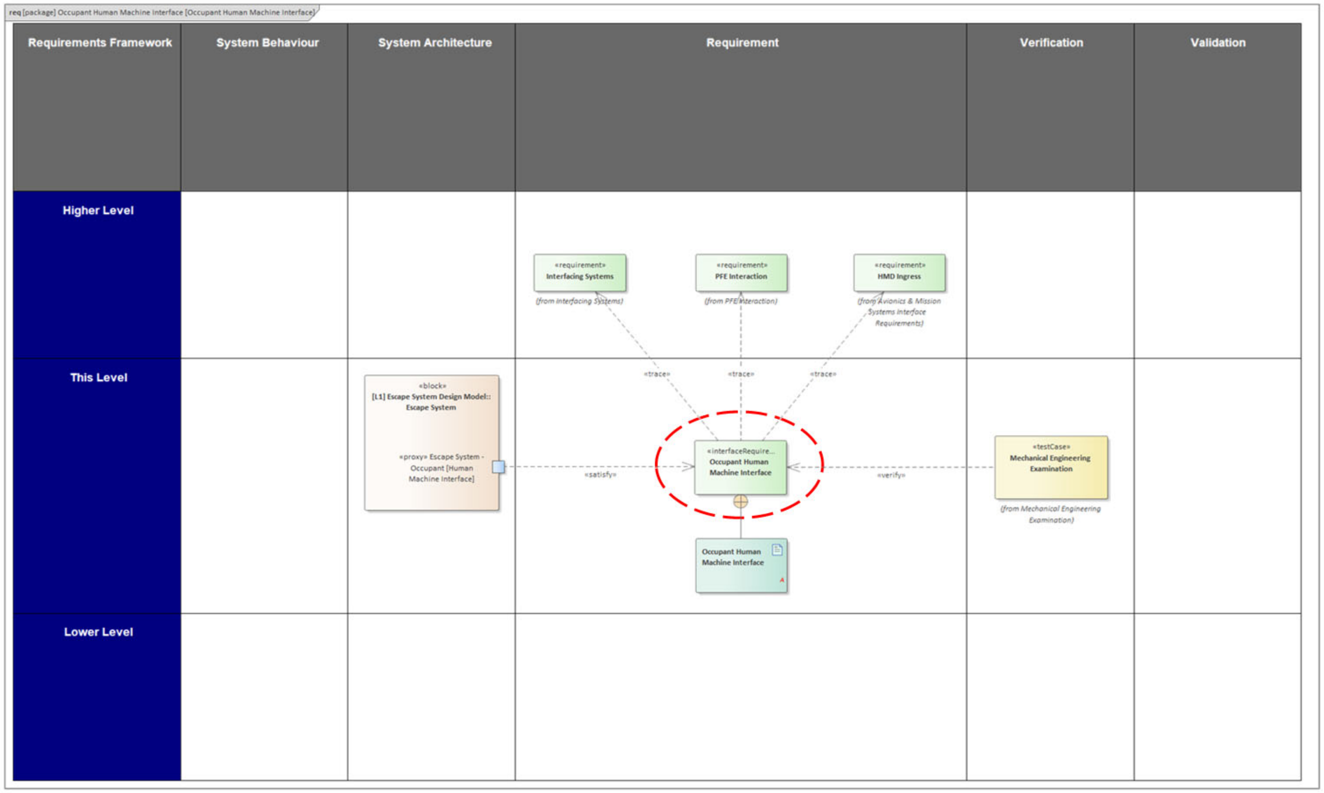
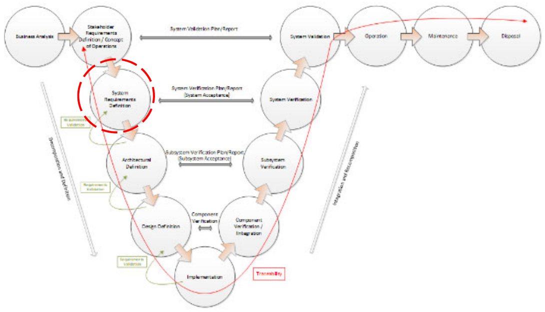
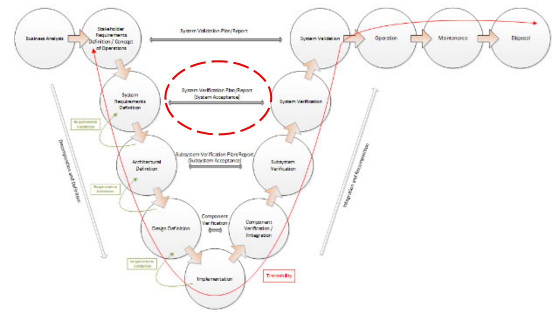
Decomposition & Definition III

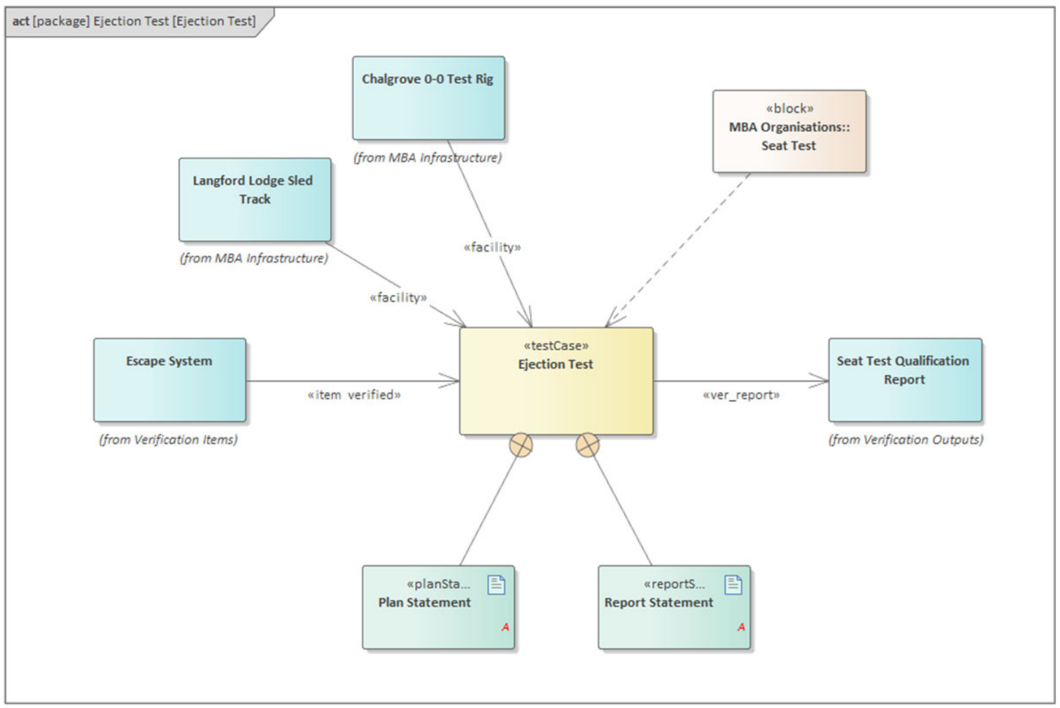




- Requirement derivation
- Requirements are documented, linked to functional/physical architecture and provide traceability to verification activities

Decomposition & Definition IV

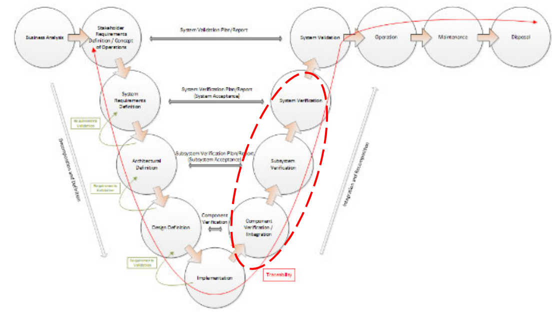


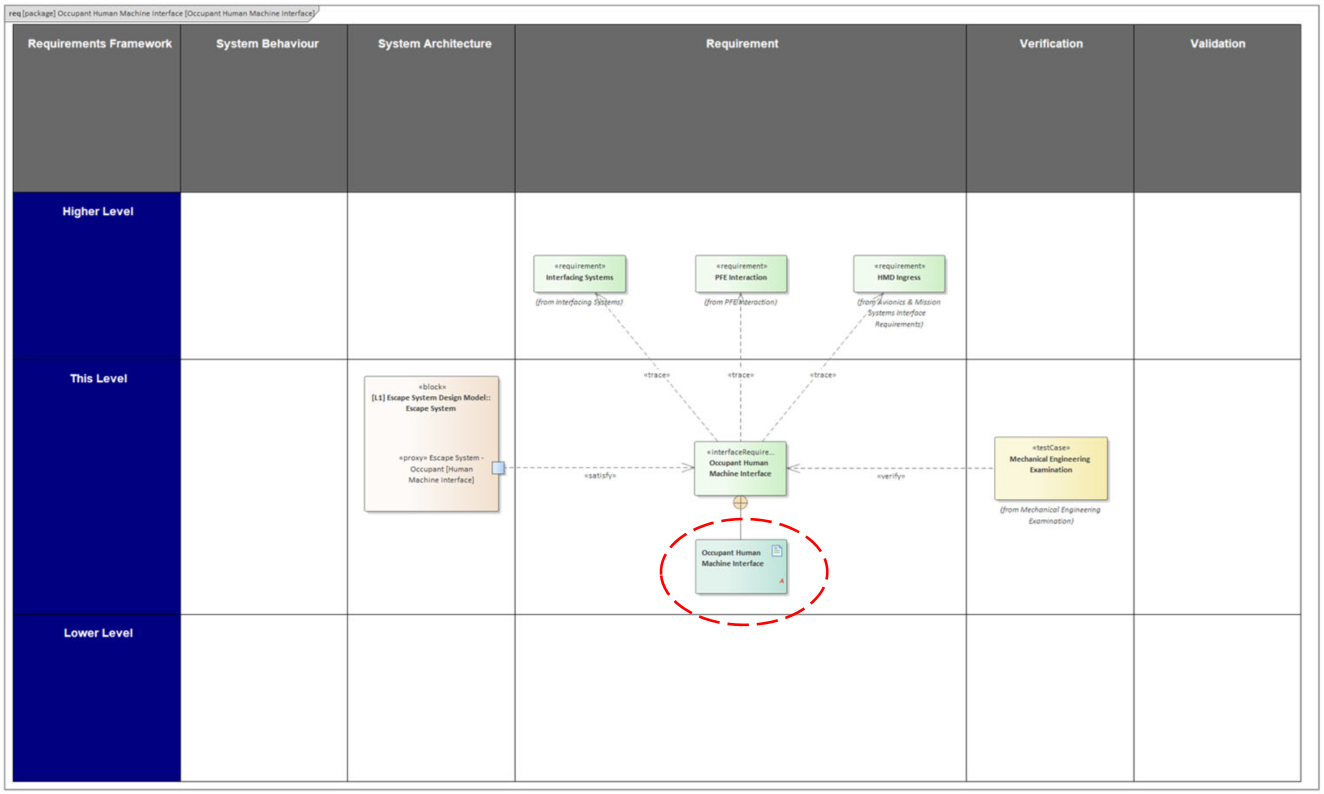


- Verification Plan defines the objective, instrumentation, data reduction and procedure of the high-level verification activities that will be conducted

- Links verification activity to applicable design, relevant infrastructure, the responsible persons and verification outputs

Integration & Recomposition





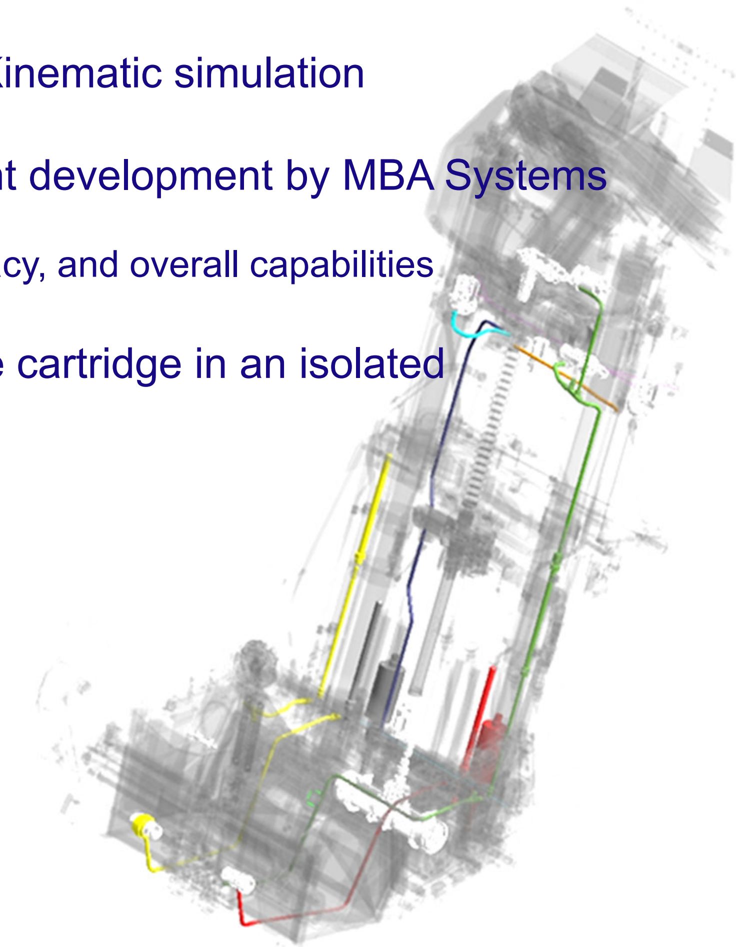
- Links original requirement to verification evidence thus providing full traceability

MBA Simulation Capability

- Top level simulation capabilities
  - **Pyrotechnic simulation (SPARK)**
  - **Escape System simulation and analysis (Seat6D)**
  - Multi-body dynamic modelling
  - Bio-dynamics and crash analysis
  - Control analysis
  - Aerodynamics and computational fluid dynamics
  - Parachute simulation
  - Software development

SPARK Overview

- **S**ystems engineering **P**yrotechnic **A**nd **R**igid body **K**inematic simulation
- Object oriented C# code created and under constant development by MBA Systems Engineering
  - Undergoing upgrades to improve performance, accuracy, and overall capabilities
- Used to simulate pyrotechnic Systems from a single cartridge in an isolated environment up to full seat representation including
  - Energy sources & sinks
    - Burning pyrotechnic charges
    - Losses
    - Orifices
  - Volumes
  - Nozzles
    - Sub & super sonic flow conditions
    - Simple quasi-1D flow
  - Pistons
  - Kinetics
  - Activators
  - Atmosphere



SPARK Capability I

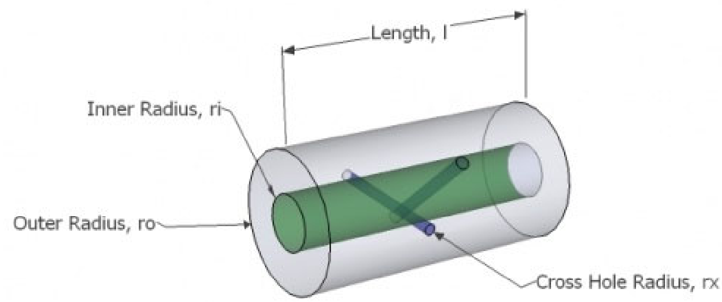
- Models use well defined chemical properties for each propellant used
  - Heat capacity ratio (Gamma)
  - Specific heat
  - Flame temperature
  - Density
  - Propellant burn rate
    - Empirical burn rate vs pressure
    - Vielle's Law

- Models typically built using engineering data
  - Catapult volume/stroke
  - Propellant slug dimensions/quantities
  - Cartridge orifice diameter

- Two types of loss object exist within SPARK
  - Thermal losses
    - Thermal flux based on temperature difference, area and material properties
    - No material thermal inertia
  - Friction losses
    - Friction losses apply a retarding force to the motion of an acceleration mass
    - Defined by a distance vs friction factor lookup up table
    - Can be varied continuously to match test data

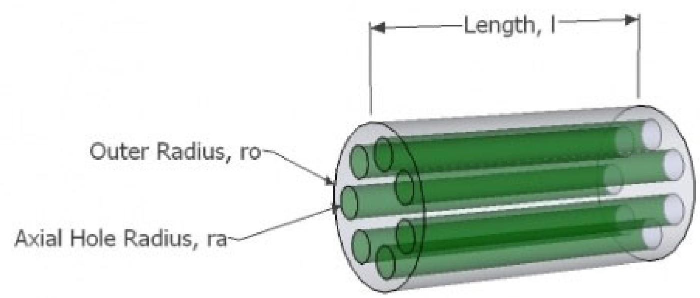
SPARK Capability II

- Pyrotechnic properties
  - For commonly used propellants (Extruded Double Base Propellant) the required properties (and composition details) are provided by the manufacturer
  - For new propellants with a known composition the propellant properties are calculated using the NASA CEA code and/or PROPEP

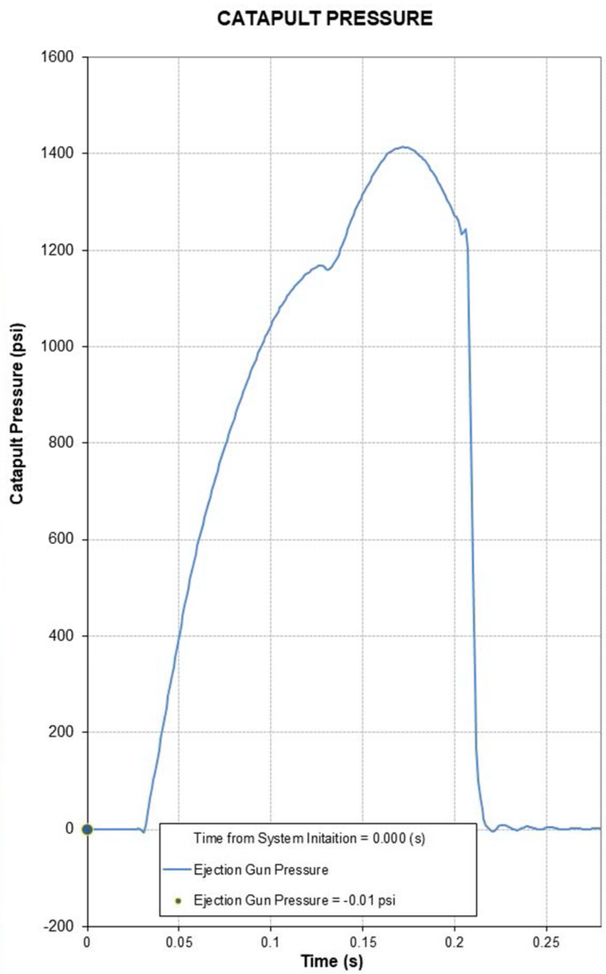


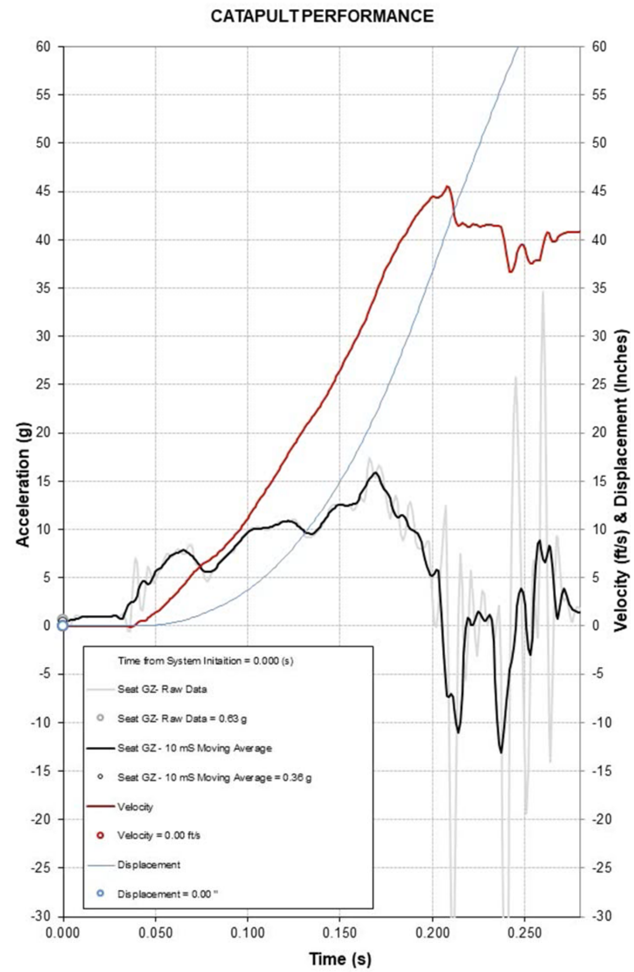
- SPARK is able to burn and evolve the surface area of some hardcoded propellant geometries
  - Solid and hollow tubes (with or without anti-resonant cross holes)
  - 7-hole perf

- Novel geometries can be input as a burn surface area vs burn depth lookup table
  - SPARK interpolates data at each time-step to generate new surface area



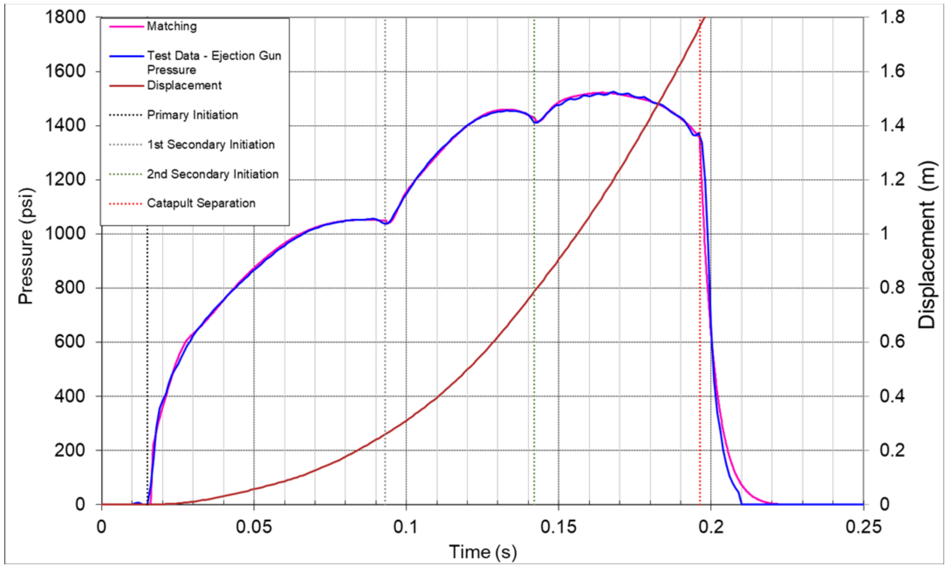
Model Validation





SPARK Uses

- Once a model has been matched, nominalised and validated, the model can be used to make predictions
- Predictions can be made of the same System under different conditions or in different configurations
- SPARK can be used to analyse Systems. Instead of performing a large number of (resource-demanding) tests, SPARK may be used instead



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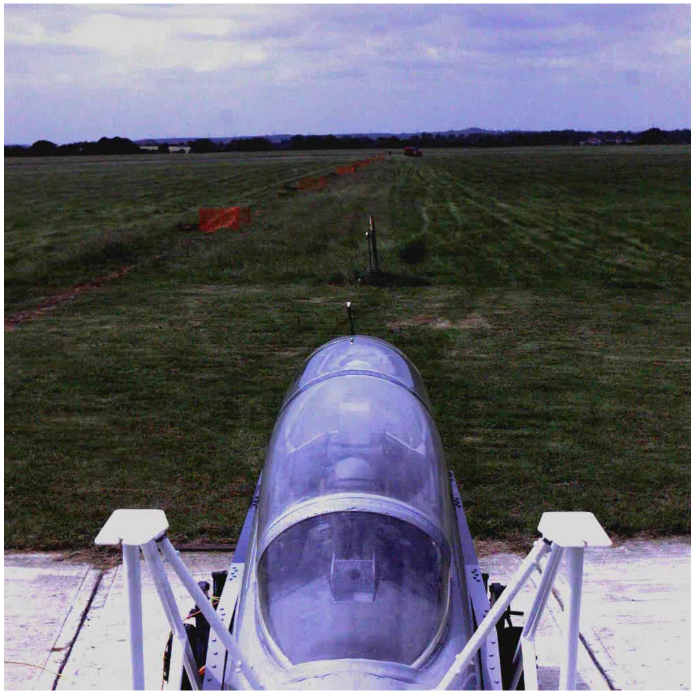
Seat6D Overview

- The object-orientated approach was used to be able to model any type of ejection seat past, present and future
  - From Mk4 to Mk18 and experimental such as controllable propulsion (e.g. NACES P3I pintle motor)

- All phases of ejection
  - From pre-ejection aircraft motion through catapult, stabilisation and parachute phases to touchdown

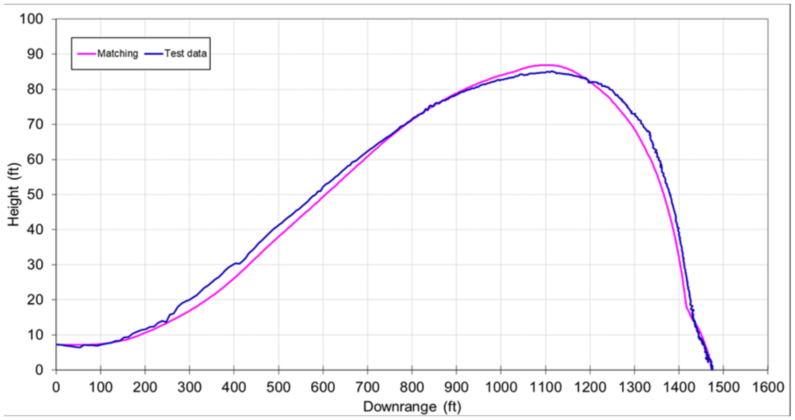
Seat6D Capability

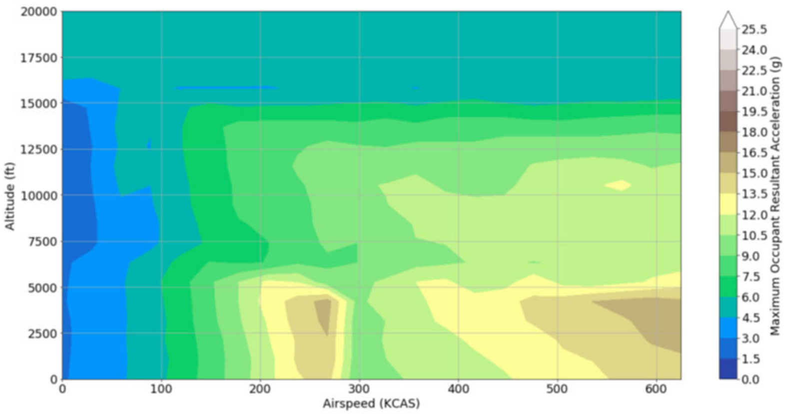
- Seat, manikin and parachutes modelled as 6 degree-of-freedom bodies
- Components/effects modelled include
  - Aircraft, canopy, catapult, rocket(s), guiderails, occupant slump, limb restraint, parachute deployment mortars, tractor rockets and slugs, bridles, risers, strops, electronic and mechanical sequencers/timers, BSTS delays, survival kit release and suspension, parachute collapse, aerodynamics on seat/parachutes (including Mach effects), aerodynamics effects of cockpit, rocket plumes and seat wake, atmospheric data (with altitude), wind …
- Types of simulation
  - Single run
  - Sensitivity – stepping through values of multiple parameters
  - Monte-Carlo – randomising (uniform, normal, user-defined) values of multiple parameters
  - Collection
- Seat6D reports various parameters and metrics back such as
  - DRI, MDRC, peak incidence/sideslip, chest gs, proximity between objects (e.g. fin clearance), terrain clearance (safe heights)



Seat6D Uses

- Seat6D calculates several key performance requirement metrics, such as:
  - MDRC
  - Seat stability (pitch and yaw angles)
  - Object trajectories
- Seat6D also calculates MBA in-house limits, that over years of extensive testing have shown to be indicative of optimal performance:
  - Maximum roll and pitch rates
  - Resultant acceleration during parachute inflation for a light crew
  - Angle of the parachute risers during lines taut
  - Minimum distances between objects
- These metrics are captured in/can be used for:
  - Performance Predictions to support Seat requirement verification
    - MDRC, chest gs, fin clearance and terrain clearance etc
  - Test prediction and analysis
    - Tests also validate models
  - System design/trade studies
  - Mishap investigations
  - Derivation of sub-system design limits
  - Crew Manual data





Seat6D Example


DANGER
EJECTION
SEAT
DANGER
DANGER
Questions?
JSF-F-35