TAI
TUSAŞ - TÜRK HAVACILIK ve UZAY SANAYİİ A.Ş.
TURKISH AEROSPACE INDUSTRIES, INC.

www.tai.com.tr
REQUIREMENT BASED ENGINEERING MANAGEMENT PROCESS TO MINIMIZE THE DESIGN DEFECTS

17. ANNUAL SYSTEMS ENGINEERING CONFERENCE
30, October 2014_Springfield, VA

Authors: Bengü YAPAR, Dilek KARACA
TAI (Turkish Aerospace Industries), Ankara - Turkey
Establishment of TAI as a joint venture to manufacture F-16 aircraft in Turkey

May 1984

January 2005

April 2005

Merger of TAI and TUSAŞ

Procurement of Lockheed Martin / General Electric shares (%49) by TUSAŞ
Manpower Histogram

Year | Count
--- | ---
2006 | 2406
2007 | 2689
2008 | 2995
2009 | 3046
2010 | 3541
2011 | 3951
2012 | 4269
2013 | 4460
2014 | 4502

TAI is an establishment of Turkish Armed Forces Foundation
TOTAL TAI ENGINEERING RESOURCES in DESIGN: 922 (As of May 2013)

- System Engineers; 75; 8%
- Manufacturing Engineers; 172; 19%
- Satellite Systems, 86, 9%
- Electrics & Avionics Engineers, 141, 15%
- MRB Engineers, 15, 2%
- Airworthiness & Safety Management, 8, 1%
- Design, Analysis, M&P Engineers, 425, 46%
• This study shows the Systems Engineering approach to solve the design sourced problems in terms of deduction.

• Instead of correction activities, prevention of the design errors during the design phase is easier, cheaper and more effective.

• For this aim, design outputs have to be checked with a proper process.

• If all output owners, checkers and approvers consider all dedicated requirements while reviewing the outputs of the design, the design errors can be eliminated before being late by creating a network which connects the requirements, outputs and the stakeholders.
FACTs ABOUT REQUIREMENTS…

“The results of the statically study for the Data Processing Technology Projects Standish in ABD performed by “Standish Group International, Inc.”

- Successful percentage of only %26
- Over cost, late or poor quality of %46
- Cancelled nearly %28
%30 of the problems are related with requirements.

%30 of the problems are related with management. (source, calendar, support).

%40 of the problems are related with the technical issues.
**INTERACTIONS WITH THE REQUIREMENTS**

Activities With the Stakeholders:

- Composing of the requirements
- Validation of the requirements
- Verification of the design

* Systems Engineering is not a throw it over the wall process.
* Be sure that all related stakeholders are in the circuit during the design phase and all of the requirements are considered.
* Verification of the design at the end of the project is too late.

A process has to be run between validation and final verification to maintain live verification phase during the whole design phase.
REQUIREMENT BASED ENGINEERING FLOWCHART FOR AIRCRAFT COMPONENTS

**Inputs**
- Contract Requirements
- Source (Procedures, Standards and Directives) Documents
- Industry Standards
- Project Constraints
- Applicable Laws and Regulations
- Engineering Experience

**Activities**
- **Analyze-Validate Requirements**
  - Validated Requirements
  - Traceability Matrices
  - Concept Documents

- **MVV Assignment**
- **Verification Criteria**
- **Concept Design**
  - Structural Tree
  - Initial Drawings
  - Initial Analysis Documents
  - Performance Measure Requirements (tests)
  - Long lead item/Equipment specifications
  - Updated Traceability Matrices
  - Initial RVTM
  - Interfaces with structural elements

- **Detailed Design**
  - Drawings
  - Analysis Documents
  - Test Documents
  - Complement Verification Proofs
  - RVTM

- **Verification**
  - Final RVTM
  - Verified System
  - Verification Report

- **Transition**
- **Can design be improved?**
- **Any deviation?**
- **GO TO PROCESS 1**
- **GO TO PROCESS 2**

**Abbreviations**
- MVV: Means of Validation & Verification
- RVTM: Requirements Verification and Traceability Matrix
- RDF: Requirement Deviation Form
PROCESS 01: VERIFICATION CRITERIA

FOR DRAWING APPROVAL, GO TO PROCESS 02

Update the Documents

Documents are sufficient and correct?

YES

GO ITEM 04

NO

Can design be improved?

YES

Signed and Accepted Documents

NO

YES

NO

03

04
Allocation of Requirements to the Checkers/Approvers by “Systems Engineering Department”

Process 02: Drawing Approval

- M&P
- F&DT
- Stress
- Maintain.
- EMI/EMC
- Weight & Balance
- Design

Released Drawings

Design is verified?

- YES
- NO

Can design be improved?

- YES
- NO

03

04

TAI is an establishment of Turkish Armed Forces Foundation
PROCESS 03: REQUIREMENT DEVIATION PROCESS

Requirement Deviation/Discrepancy Process for TAI

- Structural Requirement Document (SRD)
- System Requirement Document (SRD)

Defining the Discrepancy/Deviation from the Requirement

Completion of Section 1 and Section 2 of the TAI Requirement Discrepancy/Deviation Form (RDF)

Does Upper Level Customer Present?

Yes

Delivering the RDF to Upper Level Customer

No

Delivering the RDF to the Requirement Stakesholder

Updating the RDF

Completion of the Section 5 of the Requirement Deviation/Discrepancy Form

Discussion and Arrival to an Agreement on a way forward with the requirement stakeholders

Returning the RDF to TAI Systems Engineering Department with the Comments

Signing of the Requirement Deviation/Discrepancy Form and Delivering a Copy of the RDF to TAI

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CONSTRUCTING THE NETWORK
Requirement Set
• General
• Functional
• Design
• Physical
• Supportability / Maintainability
• Environmental Conditions
• Material and Corrosion Protection
• Load and Safety Factor
• Label and Marking
• Storage/ Package/ Transportation

Means of Compliances
- MoC 0-Compliance Statement
- MoC 1- Design Review
- MoC 2-Calculation/ Analysis
- MoC 3- Safety Analysis
- MoC 4-Laboratory Test
- MoC 5- Ground Test
- MoC 6- Flight Test
- MoC 7-Inspection
- MoC 8-Simulation
- MoC 9- Equipment Qualification

See Requirement Grouping

Outputs
- Compliance Statement Memorandum
- Signed V&V matrix Sheets
- Coordination Design Memorandums
- Technical Drawings
- System/Structure Description Document
- Reviews
- DMU Review, Weight Review, Concept Review, Design solution Review (Mat A review, PDR, CDR), DMU review (Clearance and clash review), Interface Reviews (Frontier drawings and interface drawings), Steps and Gaps review, Definition dossier Review (DFMR, DFAR, FDA), Interchangeability Review, Tolerancing Review, Maintainability, Reparability Review
- Thermal Analysis
- FEM Validation
- Static Calculation
- Fatigue Calculation
- Crack propagation Calculation (Damage tolerance)
- Deformation analysis
- Flutter Analysis
- Maintainability Analysis (QMA, MTA, GSA, preMSG3..)
- PRA Analysis
- MHEA (Maintainability Human Error Analysis)
- Items Technical Qualification
- Material Technical qualification (Metallic and composite)
- Static test (sub-component, element, coupon, detail)
- Fatigue test & Damage Tolerance Test (sub-component, element, coupon, detail)
- Lightning test Test Request/Report
- Functioning Test Request/Report
- Flight Test Request/Report
- Inspection Report by Quality Product Specialist
- Inspection Report by Authorities Specialist
- Simulation outputs to replace tests
- Simulation outputs as part of stress analysis
- Physical Modelling
- Simulation Digital Modelling (including GSA)
- Design Declaration Performace
- Qualification Summary Sheet
<table>
<thead>
<tr>
<th>Design</th>
<th>General</th>
<th>Supportability/Maintainability</th>
<th>Interface</th>
<th>Physical</th>
<th>Functional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design principles</td>
<td>Contractual Requirements</td>
<td>Lifting/Jacking concept</td>
<td>Installation design principles</td>
<td>Weight, not to exceed weight</td>
<td>Performance</td>
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<tr>
<td>Vulnerability/survivability requirements in case of a military usage</td>
<td>Certification requirements</td>
<td>Interchangeability requirements and interchangeable components</td>
<td>Tolerances</td>
<td>Dimensions in terms of width, height, cross section.</td>
<td>Speed</td>
</tr>
<tr>
<td>General tolerances</td>
<td>Directives, documents and applicable rules</td>
<td>Replaceability requirements and replaceable components</td>
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<td>Top coat application</td>
<td>Different modes in accordance with the scenarios</td>
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<td>Greasing/lubrication</td>
<td></td>
<td>Equipment, furnishing, handling systems</td>
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<tr>
<td>Roughness</td>
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<td>Accessibility</td>
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<td>Lightning strike-protection</td>
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<td>Removable elements</td>
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<td>EMI/EMC</td>
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<td>Repairability</td>
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<td>Structure assembly requirements</td>
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<td>Human health goals</td>
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<td>Design and product constraints</td>
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<td>Maintenance task</td>
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<tr>
<td>Producibility in terms of: - Chemical milling, - Cleaning, -Forging, -Forming, - Hole preparation, -Machining - Inspection</td>
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<td>Adjustment/calibration</td>
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<tr>
<td>Temperature, radiation, acoustic, pressured controlled area requirements</td>
<td>Greasing/lubrication</td>
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<tr>
<td>Requirement Grouping</td>
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<tr>
<td>Environmental</td>
<td>Materials &amp; Corrosion Protection</td>
<td>Load and Safety Factor Load</td>
<td>Storage/Package/Transportation</td>
<td>Label &amp; Marking</td>
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<tr>
<td>Temperature/Temperature variation/Altitude</td>
<td>Material/Part reference documents</td>
<td>Fatigue loads design criteria:</td>
<td>Transportation/delivery related requirements</td>
<td>Marking (placards, nameplates, stencils, markings)</td>
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<tr>
<td>Humidity</td>
<td>Material</td>
<td>- For structural loads for fatigue and damage tolerance</td>
<td>Packaging/Storage</td>
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<tr>
<td>Operational Shocks</td>
<td>Heat treatment</td>
<td>- For crash loads</td>
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<td>Crash safety</td>
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<tr>
<td>Vibration</td>
<td>Corrosion protection practices i.a.w zones</td>
<td>Damage tolerance/resistance</td>
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<td>Explosion Proofness</td>
<td>Chemical surface treatments</td>
<td>Minimizing risk of damage</td>
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<td>Waterproofness</td>
<td>Sealant application</td>
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<td>Fluid susceptibility</td>
<td>Primer application</td>
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<td>Sand and dust</td>
<td>Lacquer application</td>
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<tr>
<td>Fungus Resistance</td>
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<td>Salt spray</td>
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<td>Magnetic Effect</td>
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<td>Power Input</td>
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<td>Voltage Spike</td>
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<td>Audio Frequency susceptibility</td>
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<td>Emission of radio frequency energy</td>
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<td>Lightning direct effects</td>
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<tr>
<td>Icing</td>
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<td>Electrostatic Discharge</td>
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<td>Fire, Flammability</td>
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<td>Erosion</td>
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<tr>
<td>Ditching</td>
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</table>
Stakeholders

- Checker
- Approver
- Customer
- Designated Certification Specialist
- Process Customer
- Designer
- Analyst
- Static
- Fatigue
- M&P
- Weight & Balance
- Designated Certification Specialist
- Program Manager
- Supportability
- Load Res.
- Systems Engineering

OK (√)

NOT APPLICABLE (-)

NOTOK (X)
If the design can be improved?

**NOTOK (X)**

**DEVIAITION SHEET**

This section is filled by the B.O.A. The deviation is the acceptance of one or several non-compliance described in the R&D. Therefore one or several BOD are included hereafter by a copyrighth by the B.O.A.

<table>
<thead>
<tr>
<th>Aircraft level analysis requested</th>
<th>Deviation Reference:</th>
<th>Issue:</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ] Minor</td>
<td>[ ] Major</td>
<td>DEV_DAORD_V5760RE11045</td>
</tr>
</tbody>
</table>

Submit Date: 13/05/2011  
Target Date: 27/05/2011  
Status: open

**TITLE:** Adjustment of side seals after replacement cannot be avoided.

- **RDF Number:**
- **SIRD/SDR Reference and Revision:**
- **SIRD/SDR Title:**
- **Requirement ID Number:**
- **Requirement Text:**
- **Allocation:**
- **Rationale:**
- **Source:**
- **Additional Information:**
- **MoC Attributes:**
- **Discrepancy/Deviation Details:**
- **Mitigation + Proposed Solution:**
- **Action Responsible / Target Date:**
- **Does the discrepancy/deviation affect key milestones e.g. Power-on, First Flight, etc?**
- **Does the discrepancy/deviation have any aircraft limitation?**
- **What is the nature of the limitations e.g. Supportability, Maintainability, performance, etc?**

Documents can be signed now!

Upissue the Documents
The doors shall be capable of manual opening and closing from inside the Aircraft and capable of manual door opening from outside. Such door, when closed, shall be capable of being locked mechanically from inside of the Aircraft in order to secure such Aircraft.

Don't forget! The Supplier Outputs shall be Traced.
The door shall have a diameter of not less than \( XX \) m.
All adjustment points shall be readily and permanently identifiable, accessible and be protected against corrosion per XX category.

**REQUIRED VERIFICATION METHODS/OUTPUTS/STAKEHOLDERS**

- **MoC 7**
  - Inspection Reports
  - Quality Product Specialist
  - Supportability Responsible
  - Designated Certification Specialist

- **MoC 2**
  - QMA
  - Supportability Responsible
  - Designer/Checker/Approver

- **MoC 9**
  - DDPs
  - Qualification Responsible
  - Designer
  - Designated Certification Specialist

- **MoC 1**
  - Part Drawings
  - Structure/System Description Document
  - Part Drawings
  - Designer/Checker/Approver
  - Supportability M&P
CASE STUDY (5/5)

CHECKLIST

Analyst

REQ-StRD-Doors-1
REQ-StRD-Doors-12
REQ-StRD-Doors-13
REQ-StRD-Doors-18
REQ-StRD-Doors-19
REQ-StRD-Doors-22
REQ-StRD-Doors-25
REQ-StRD-Doors-50
REQ-StRD-Doors-62
REQ-StRD-Doors-67
REQ-StRD-Doors-72
REQ-StRD-Doors-82

FEM Validation
Thermal Analysis
Crack Propagation Calculation
Static Calculation
Deformation analysis

CHECKLIST

Analyst

REQ-StRD-Doors-1
REQ-StRD-Doors-2

FEM Validation
Thermal Analysis
Crack Propagation Calculation
Static Calculation
Deformation analysis

REQ-StRD-Doors-249
REQ-StRD-Doors-250

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CONCLUSION

STAKEHOLDERS

• Checker
• Approver
• Customer
• Designated Certification Specialist
• Process Customers
  • Designer
  • Analyst
    • Static
    • Fatigue
• M&P
• Weight&Balance
• Designated Certification Specialist
• Program Manager
• Supportability Responsible
• Load Responsible
• Systems Engineering
• Test Responsible

O U T P U T s

• Compliance Statement Memorandum
• Signed V&V matrix Sheets
• Coordination Design Memorandums
• Technical Drawings
• System/Structure Description Document
• Crack propagation Calculation (Damage tolerance)
• Reviews
  • DMU Review, Weight Review, Concept Review, Design solution Review (Mat A review, PDR, CDR), DMU review (Clearance and clash review), Interface Reviews (Frontier drawings and interface drawings), Steps and Gaps review, Definition dossier Review (DFMR, DFAR, FDA), Interchangeability Review, Tolerancing Review, Maintainability, Reparability Review
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• Simulation outputs to replace tests
• Simulation outputs as part of stress analysis
• Physical Modelling
• Simulation Digital Modelling (including GSA)
• Design Declaration Performance
• Qualification Summary Sheet

C H E C K L I S T

Allocated Req.

REQ-StRD-Doors-1
REQ-StRD-Doors-2
REQ-StRD-Doors-249
REQ-StRD-Doors-250

OK (√)

NOTOK (X)

30 of 32
✓ Writing Good Technical Requirements in Aviation_ Bengü YAPAR, Dilek KARACA, Engin ÖNCÜL-16th NDIA Systems Engineering Conference


✓ Telelogic Presentation

✓ INCOSE HandBook
THANK YOU