
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

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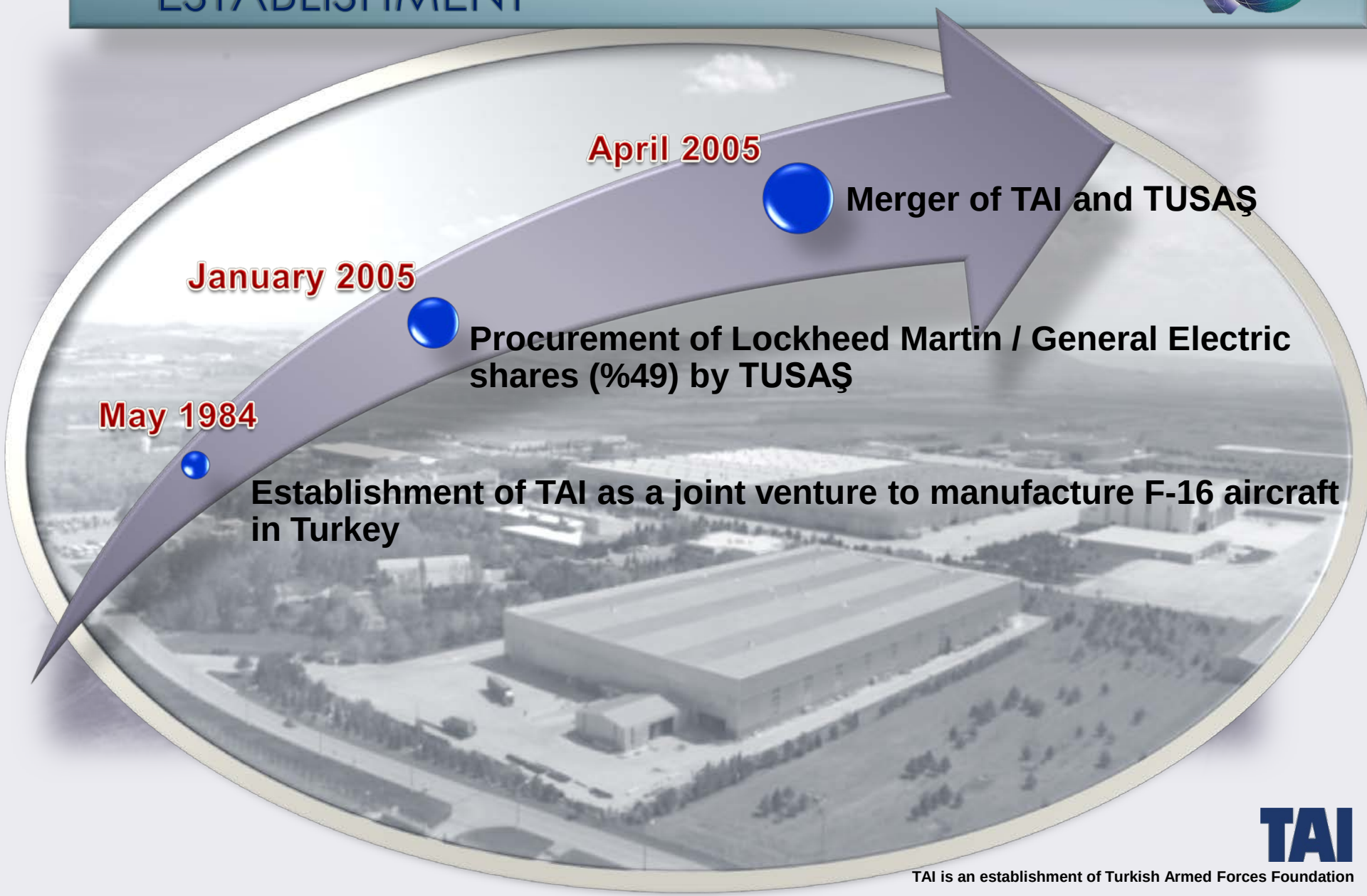
TAI (Turkish Aerospace Industries), Ankara - Turkey

WHO WE ARE?
ESTABLISHMENT



April 2005

Merger of TAI and TUSAŞ

January 2005

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

May 1984

Establishment of TAI as a joint venture to manufacture F-16 aircraft in Turkey

STRATEGICAL BUSINESS UNITS

AIRCRAFT

UAV SYSTEMS

HELICOPTER

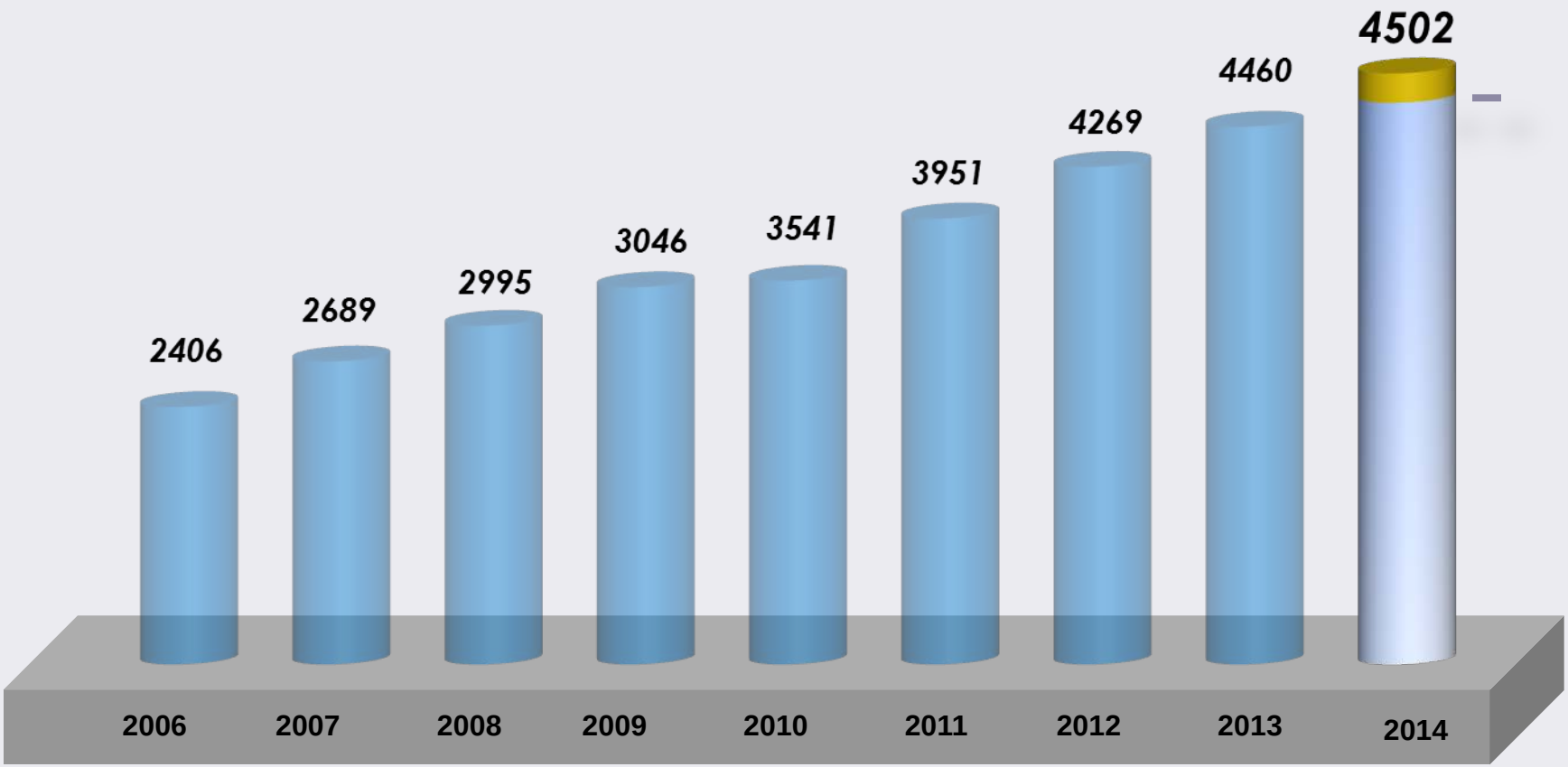
SPACE SYSTEMS

AEROSTRUCTURES

SPECIAL PROGRAMS

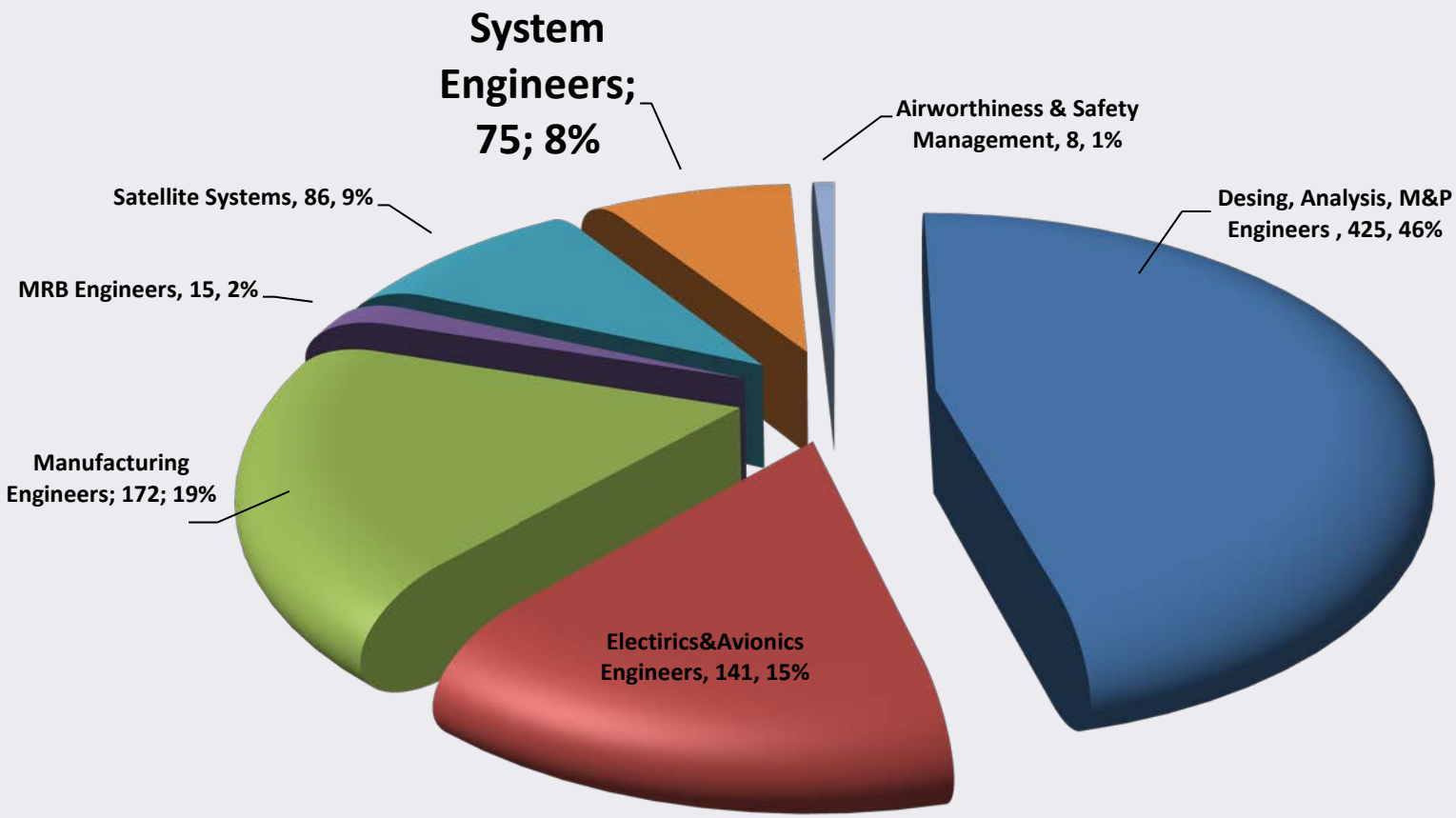
HUMAN RESOURCES

Manpower Histograph



OVERVIEW OF ENGINEERING MANPOWER INFORMATION

TOTAL TAI ENGINEERING RESOURCES in DESIGN : 922 (As of May 2013)



INTERNATIONAL CUSTOMERS

- BAE SYSTEMS
- BOEING
- BOMBARDIER
- LMAC
- LMMFC
- MARVIN ENGINEERING
- NORTHROP GRUMMAN
- SIKORSKY
- SPIRIT AEROSYSTEMS
- AGUSTA WESTLAND
- AIRBUS SPAIN
- AIRBUS MILITARY
- ALENIA AERMACCHI
- EADS-EUROCOPTER
- FOKKER
- IAMCO
- PAG
- RUAG AEROSPACE
- TELESPAZIO
- THALES

INDEX

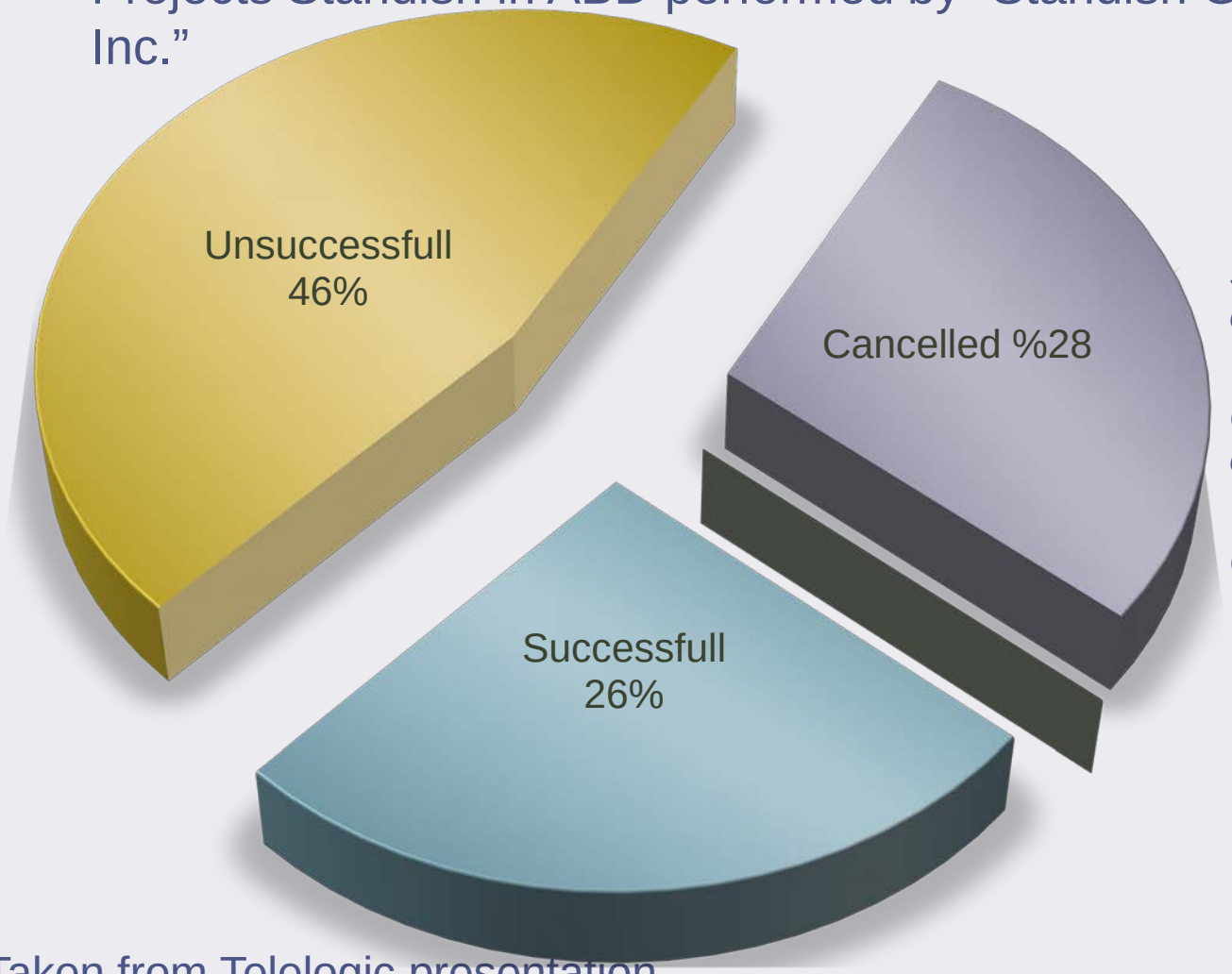
- Who we are?
- Scope
- Facts About Requirements
- Requirement Based Engineering Flowchart for Aircraft Projects
- Requirement Based Engineering Flowchart for Aircraft Components
- Verification Criteria
- Drawing Approval
- RDF
- Construction the Network

SCOPE

- 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

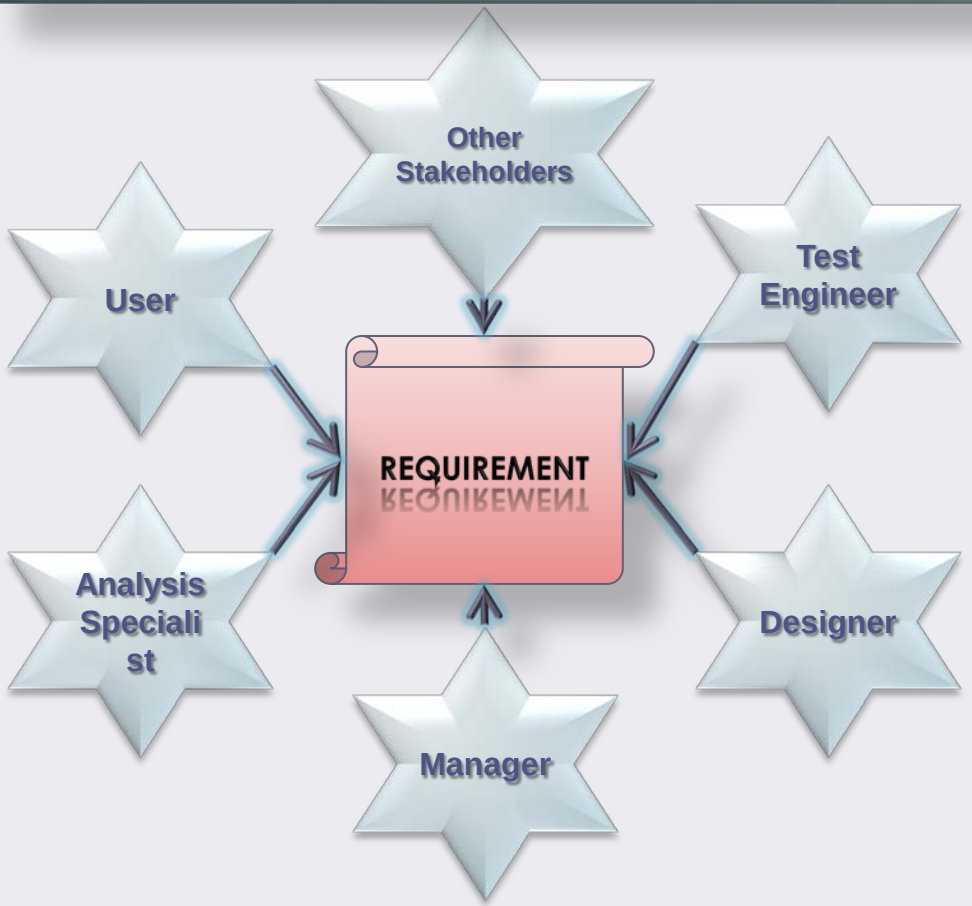
Cancelled nearly %28

Taken from Telelogic presentation

AS A CONCLUSION…

- %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 PROJECTS

- Source Documents
- Stakeholder Needs
- Project Constraints

ACTIVITIES
- Elicit Stakeholder Requirements
- Define Stakeholder Requirements
- Analyze and Maintain Stakeholder Requirements

X Y

- Validation Criteria **(B)**

- Stakeholder Requirements **(K)**
- Measures of Effectiveness Needs
- Measures of Effectiveness Data
- Initial RVTM
- Stakeholder Requirements Traceability
- Concept Documents **(A)**

ACTIVITIES
- Define the System Requirements
- Analyze and Maintain the System Requirements

X Y

- Measures of Performance Needs
- Measures of Performance Data
- Verification criteria **(C)**

Implementation Enabling Systems

X Y

ACTIVITIES
- Plan the Implementation
- Perform Implementation

A + B + C

- Specification Tree**(D)**
- System specification
- Updated RVTM **(E)**
- System Requirements Traceability
- System Requirements **(F)**
- System Functions
- System Functional Interfaces

- System Architecture Description
- Interface Requirements **(G)**
- System Element Requirements
- System Element Descriptions
- System Element Requirements Traceability

ACTIVITIES
- Define the Architecture
- Analyze and Evaluate the Architecture
- Document and Maintain The Architecture

X Y

- Technical Performance Measures Needs
- Technical Performance Measures Data

- Implementation Strategy
- Implementation Enabling System Requirements
- Implementation Constraints on Design
- Operator/Maintainer Training **(H)**
- Initial Trained Operators and Maintainers **(I)**

Verification Enabling Systems

- Life Cycle Constraints
- +
- **A**

C + D + E + F + G

ACTIVITIES
- Plan Verification
- Perform Verification

X Y

- Final RVTM **(L)**
- Verified System
- Verification Report

Integration Enabling Systems

- System Elements
- System Element Documentation
- System Element Descriptions

ACTIVITIES
- Plan Integration
- Perform Integration

X Y

- Integrated System
- Interface Control Documents **(J)**
- Integration Report

- Integration Strategy
- Integration Enabling System Requirements
- Integration constraints on Design
- Integration Procedure

- Verification Strategy
- Verification Enabling System Requirements
- Verification Constraints on Design
- Verification Report

A + H + I + J

X Y

ACTIVITIES
- Plan the Transition
- Perform the Transition

- Accepted System
- **G**

A

Validation Enabling Systems

- Validated System
- Validation Report

ACTIVITIES
- Plan Validation
- Perform Validation

X Y

A + B + L + K

- Installed System
- Transition Report

Transition Enabling Systems

Disposal Enabling Systems

X Y

ACTIVITIES
- Plan Disposal
- Perform Disposal
- Finalize the Disposal

Maintenance Enabling Systems

A + H + I

X Y

ACTIVITIES
- Plan Maintenance
- Perform Maintenance

X Y

ACTIVITIES
- Prepare for Operation
- Perform Operational Activation and Check-out
- Use System for Operations
- Perform Operational Problem Resolution
- Support the Customer

Operation Enabling Systems

- Validation Strategy
- Validation Enabling System Requirements
- Validation Constraints on Design
- Validation Report

- Transition Strategy
- Transition Enabling System Requirements
- Transition Constraints on Design
- Installation Report

- Disposal Strategy
- Disposal Enabling System Requirements
- Disposal Constraints on Design
- Disposal Report
- Disposal Procedure
- Disposed System

- Maintenance Strategy
- Maintenance Enabling System Requirements
- Maintenance Constraints on Design
- Maintenance Report
- Maintenance Procedure

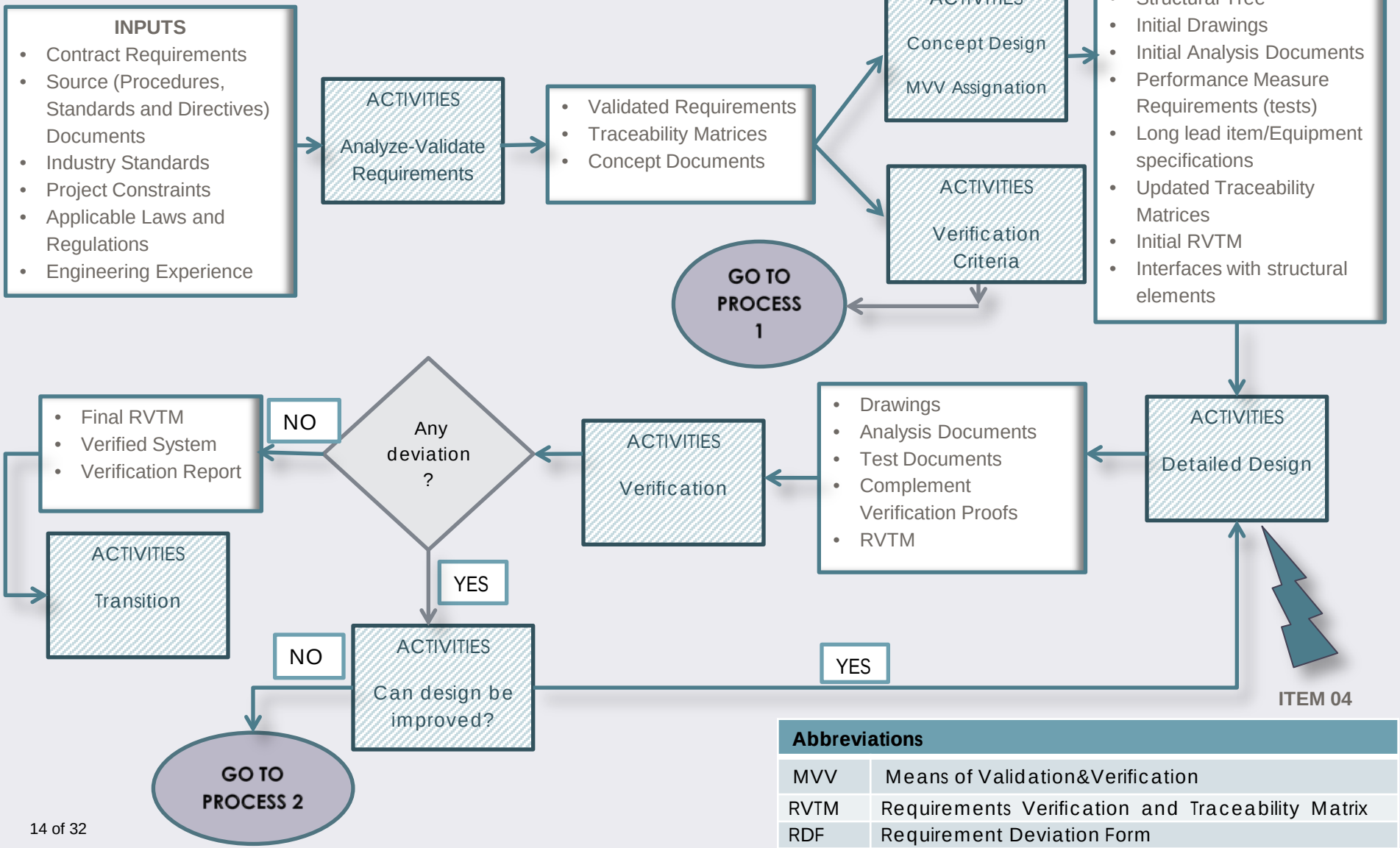
- Operation Strategy
- Operation Enabling System Requirements
- Operation Constraints on Design
- Operation Report

CONTROLS (X)
- Applicable Laws and Regulations
- Industry Standards
- Agreements
- Project Procedures and Standards
- Project Directives

ENABLERS (Y)
- Organization/Enterprise Policies, Procedures and Standards,
- Organization/Enterprise Infrastructure
- Project Infrastructure

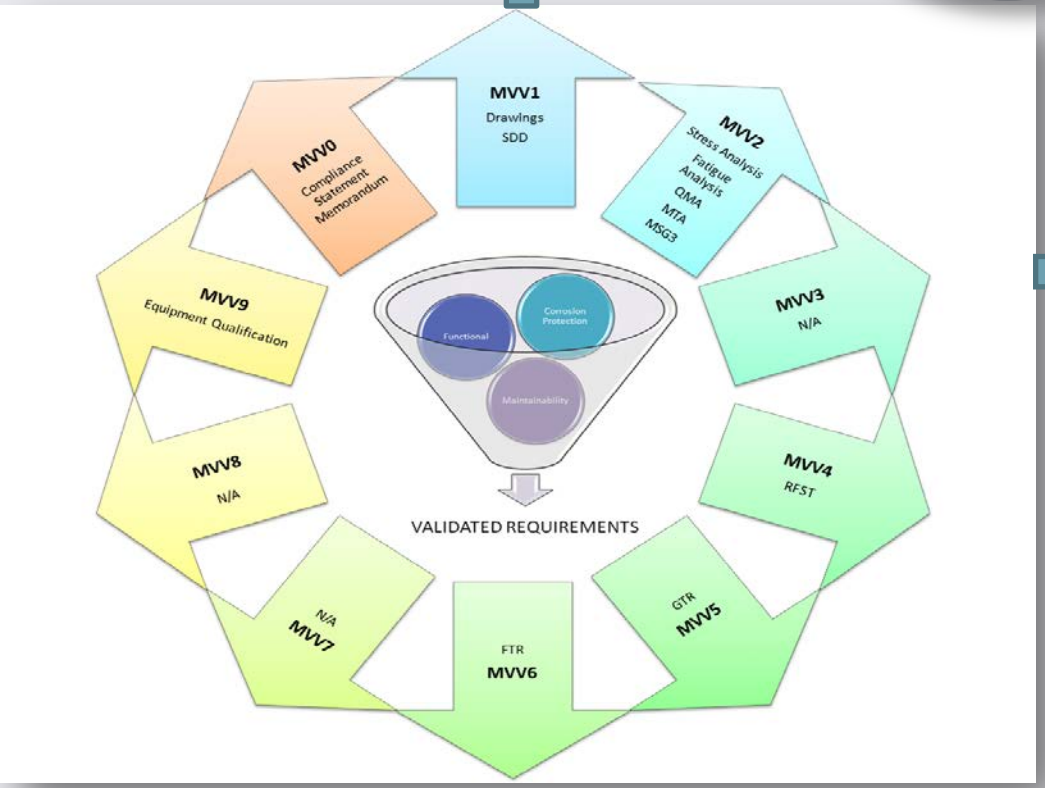
Composed from INCOSE Handbook

REQUIREMENT BASED ENGINEERING FLOWCHART FOR AIRCRAFT COMPONENTS



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

NO

Documents are sufficient and correct?

YES

Design is Verified ?

NO

Can design be improved? ?

YES

GO ITEM 04

YES

Signed and Accepted Documents

NO

03

PROCESS 02: DRAWING APPROVAL

Allocation of Requirements to the Checkers/Approvers by "Systems Engineering Department"

M&P

F&DT

Stress

Maintain.

EMI /EMC

Weight& Balance

Design

Released Drawings

YES

Design is verified?

NO

Can design be improved ?

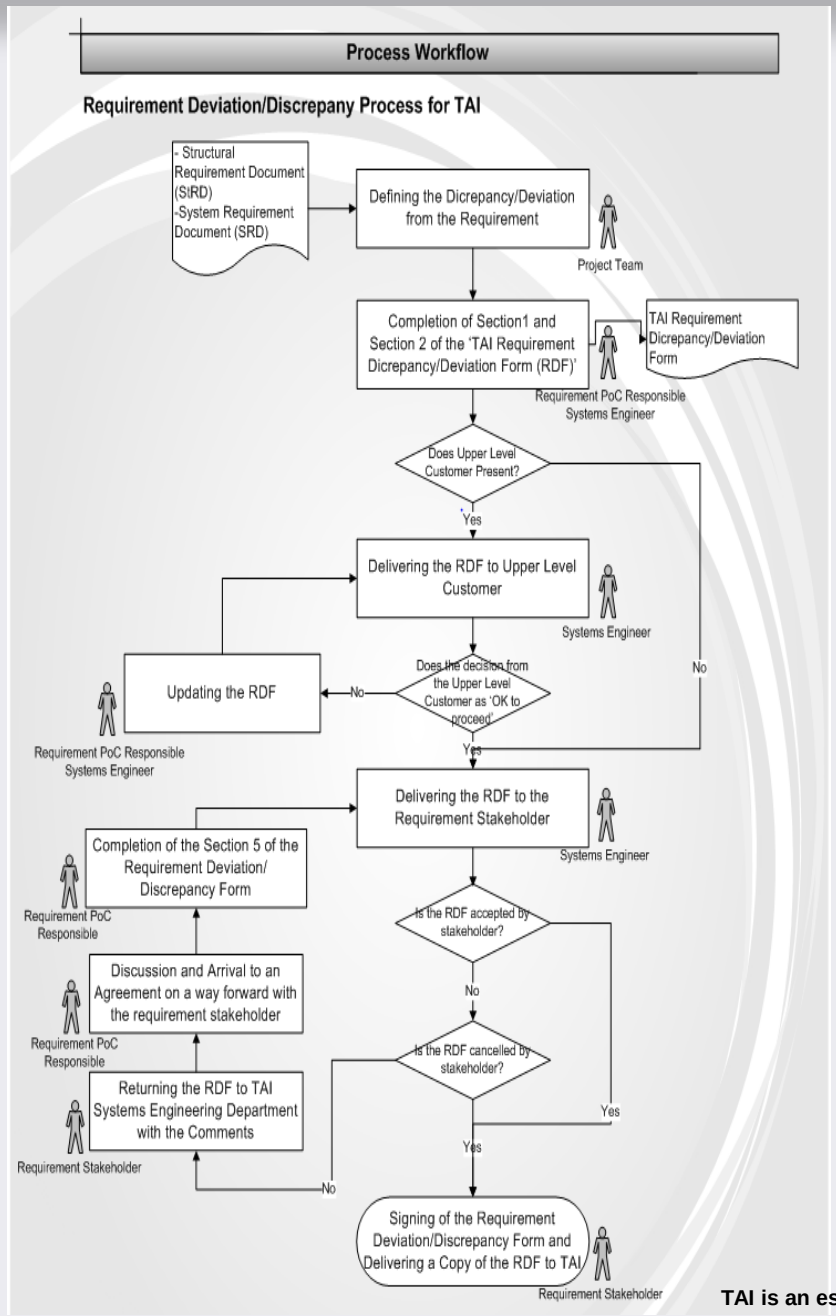
YES

GO ITEM 04

NO

03

PROCESS 03: REQUIREMENT DEVIATION PROCESS



CONSTRUCTING THE NETWORK

PROCESS FOR CONSTRUCTING THE NETWORK (1/6)

Requirement Set

- General
- Functional
- Design
- Physical
- Supportability / Maintainability
- Environmental Conditions
- Material and Corrosion Protection
- Load and Safety Factor
- Label and Marking
- Storage/ Package/ Transportation

See Requirement Grouping

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

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)
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- 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 Summmary Sheet

PROCESS FOR CONSTRUCTING THE NETWORK (2/6)

Design	General	Supportability / Maintainability	Interface	Physical	Functional
Design principles	*Contractual Requirements*	*Lifting/Jacking concept*	*Installation design principles*	*Weight, not to exceed weight*	*Performance*
Vulnerability/survivability requirements in case of a military usage	*Certification requirements*	*Interchangeability requirements and interchangeable components*	*Tolerances*	*Dimensions in terms of width, height, cross section.*	*Speed*
General tolerances	*Directives, documents and applicable rules*	*Replaceability requirements and replaceable components*		*Top coat application*	*Different modes in accordance with the scenarios*
Greasing/lubrication		*Equipment, furnishing, handling systems*			
Roughness		*Accessibility*			
Lightning strike-protection		*Removable elements*			
EMI/EMC		*Repairability*			
Structure assembly requirements		*Human health goals*			
Design and product constraints		*Maintenance task*			
Producibility in terms of: - Chemical milling, - Cleaning, -Forging, - Forming, - Hole preparation, -Machining - Inspection		*Adjustment/calibration*			
Temperature , radiation, acoustic, pressured controlled area requirements					
Greasing/lubrication					

Requirement Grouping

PROCESS FOR CONSTRUCTING THE NETWORK (3/6)

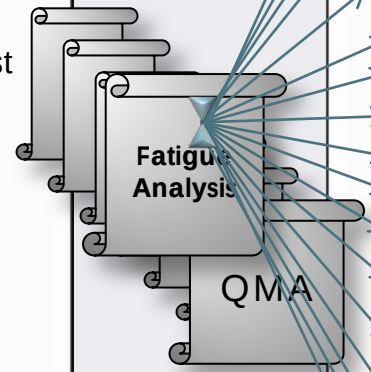
Environmental	Materials & Corrosion Protection	Load and Safety Factor Load	Storage/ Package/ Transportation	Label & Marking
Temperature/Temperature variation/Altitude	*Material/Part reference documents*	*Fatigue loads design criteria:*	*Transportation /delivery related requirements*	*Marking (placards, nameplates, stencils, markings)*
Humidity	*Material*	*- For structural loads for fatigue and damage tolerance*		
Operational Shocks	*Heat treatment*			
Crash safety		*- For crash loads*	*Packaging /Storage*	
Vibration	*Corrosion protection practices i.a.w zones*	*Damage tolerance/resistance*		
Explosion Proofness	*Chemical surface treatments*	*Minimizing risk of damage*		
Waterproofness	*Sealant application*			
Fluid susceptibility	*Primer application*			
Sand and dust	*Lacquer application*			
Fungus Resistance				
Salt spray				
Magnetic Effect				
Power Input				
Voltage Spike				
Audio Frequency susceptibility				
Emission of radio frequency energy				
Lightning direct effects				
Icing				
Electrostatic Discharge				
Fire, Flammability				
Erosion				
Ditching				

Requirement Grouping

PROCESS FOR CONSTRUCTING THE NETWORK (4/6)

Responsibles

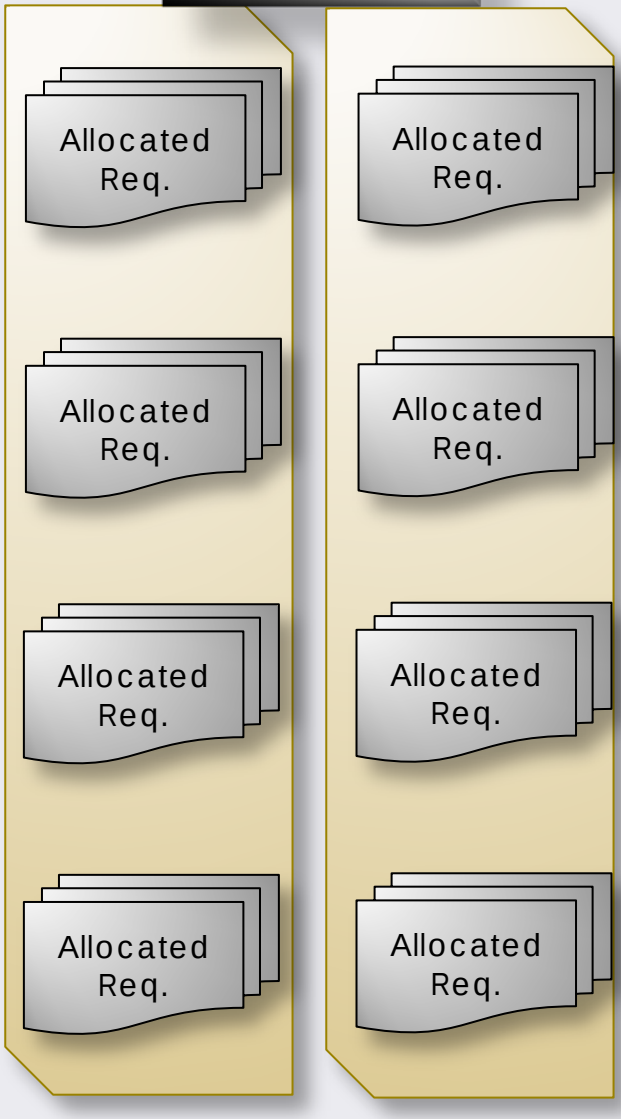
- Designer
- Analist
  - Static
  - Fatigue
- M&P
- Weight&Balance
- Designated Certification Specialist
- Program Manager
- Supportability
- Load Res.
- Systems Engineering
- Test Responsible



Stakeholders

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

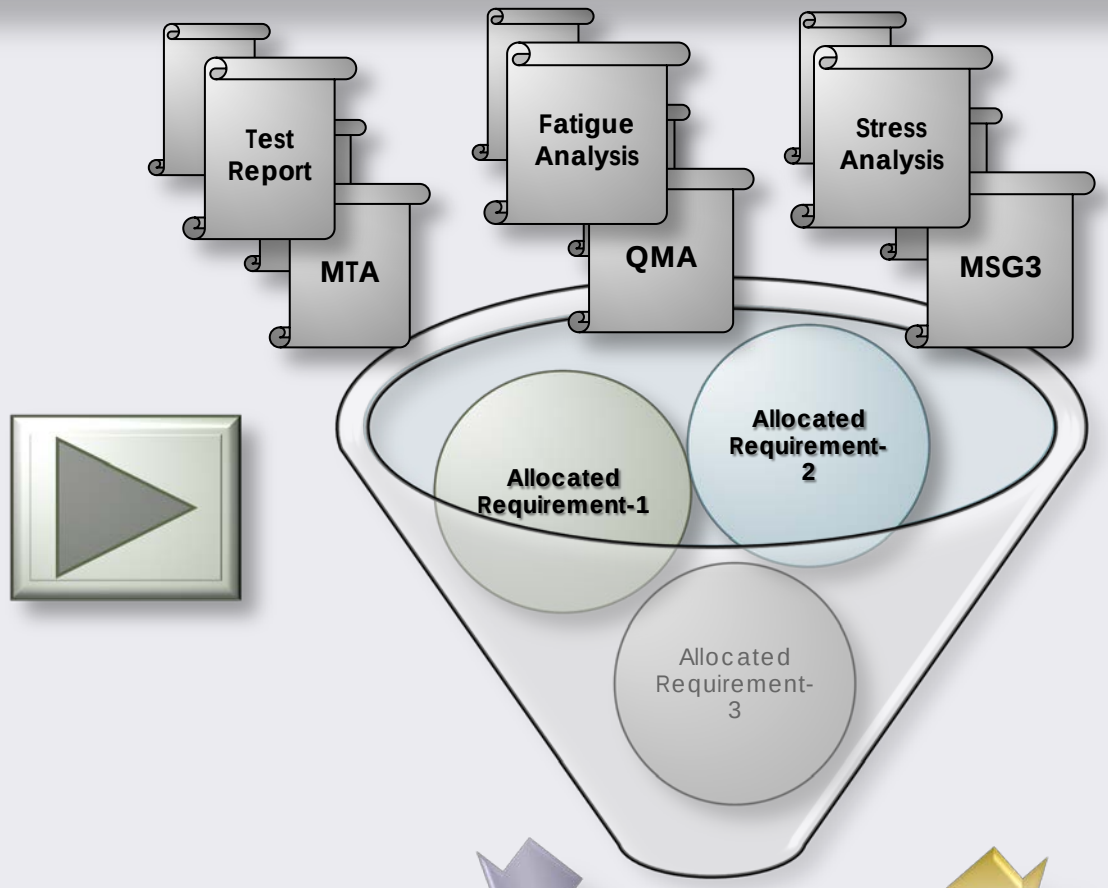
Stakeholder Checklists



PROCESS FOR CONSTRUCTING THE NETWORK (5/6)

Stakeholders

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



OK (√)

NOT APPLICABLE (-)

NOT OK (X)

Document can be Signed

PROCESS FOR CONSTRUCTING THE NETWORK (6/6)

NOT OK (X)

DEVIATION SHEET

This section is filled by the B.O.S. The deviation is the acceptance of one or several non-compliance described in the RDF. Therefore one or several RDF are included hereafter by a copy/paste by the B.O.S.

☐ Aircraft level analysis requested	Deviation Reference:	DEV_DAORD_V5760RE11045 45	Issue:	01	
☒ Minor/ ☐ Major	Submit Date:	13/05/2011	Target date:	27/05/2011	
	Status:	open			
TITLE:	Adjustment of side seals after replacement cannot be avoided.				

RDF Number:
StRD/SRD Reference and Revision:
StRD/SRD 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?

NO

If the design can be Improved?

YES

Documents can be signed now!

Test Report

MTA

Fatigue Analysis

QMA

Stress Analysis

MSG3

Upissue the Documents

CASE STUDY (1/5)

Functional Requirement

REQ-StRD-Doors-1

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.

REQUIRED VERIFICATION METHODs/OUTPUTs/STAKEHOLDERs

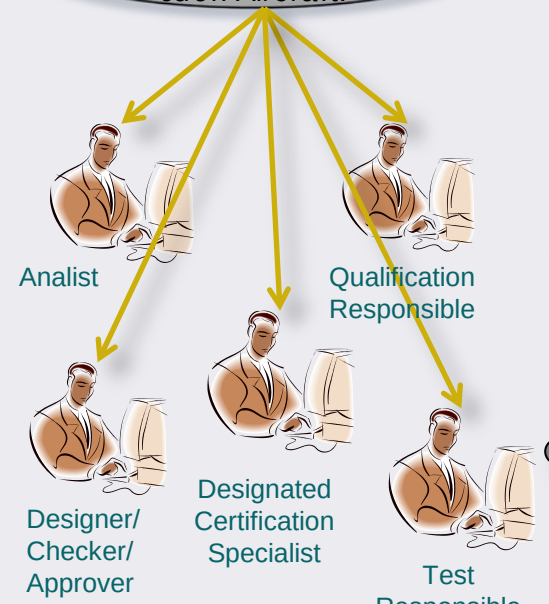
MoC 2	MoC 4	MoC 5	MoC 9
FEM Validation	Jamming Test Request /Report	Ground Test Request / Report	DDPs for operating mechanism
Static Calculation	Functional Test Request /Report		
Jamming Analysis			
Deformation Analysis			

Analist
Designated Certification Specialist

Analist
Designer
Test Responsible
Qualification Responsible
Designated Certification Specialist

Analist
Designer
Test Responsible
Qualification Responsible.
Designated Certification Specialist

Analist
Designer
Test Responsible
Qualification Responsible
Designated Certification Specialist



Don't forget!
The Supplier Outputs shall be Traced.

CASE STUDY (2/5)

REQUIRED VERIFICATION METHODs/OUTPUTs/STAKEHOLDERs

Physical Requirement

REQ-StRD-Doors-2

The door shall have a shall have a diameter of not less than XX m.

Designer/
Checker/
Approver

MoC 1-Design Review

- Part Drawing 57D001 — Designer
- Part Drawing 57D002 — Designer
- Part Drawing 57D003
- DMU Review — Designer
- Structure Description Document — Designer
- Concept Review
- Interface Review
- Design solution Review (Mat A review, PDR, CDR),

Don't forget!
Information for all "Stakeholders"

CASE STUDY (3/5)

Supportability &Corrosion Protection

REQ-StRD-Doors-3

All adjustment points shall be readily and permanently identifiable , accessible and be protected corrosion per XX category.

REQUIRED VERIFICATION METHODs/OUTPUTs/STAKEHOLDERs

MoC 7	MoC 2	MoC 9	MoC 1
Inspection Reports	QMA	DDPs	Part Drawings
Quality Product Specialist	Supportability Res. Designer	Qualification Responsible Designer Designated Certification Specialist	Structure/ System Description Document
			Part Drawings
			Designer/Checker/Approver Supportability M&P

CASE STUDY (4/5)

Designer/
Checker/
Approval

CHECKLIST

REQ-StRD-Doors-1

REQ-StRD-Doors-2

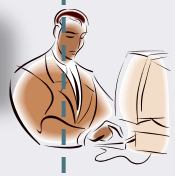
REQ-StRD-Doors-3

REQ-StRD-Doors-1

Analist

M&P

Qualification
Responsible



Test Responsible

CHECKLIST

REQ-StRD-Doors-3

REQ-StRD-Doors-1

REQ-StRD-Doors-3

REQ-StRD-Doors-1

Designated
Certification
Specialist

Quality
Product
Specialist

Supportability
Responsible

CHECKLIST

REQ-StRD-Doors-1

REQ-StRD-Doors-3

REQ-StRD-Doors-3

REQ-StRD-Doors-3

FEM Validation

Static Calculation

Functional Test Request /Report

Ground Test Request / Report

Inspection Reports

Structure/ System Description Document

DMU Review

Concept Review

Deformation Analysis

Jamming Analysis

Jamming Test Request /Report

DDPs for operating mechanism

QMA

Design solution Review

Interface Review

Part Drawing

Interface Review

CASE STUDY (5/5)

Analysist

CHECKLIST

- 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

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

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

CONCLUSION

STAKEHOLDERS

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

OUTPUTs

- 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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- Maintainability Analysis (QMA, MTA, GSA, preMSG3..)
- PRA Analysis
- MHEA (Maintainability Human Error Analysis)
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- Material Technical qualification (Metallic and composite)
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- 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 Summmary Sheet

CHECKLIST

Allocated Req.

REQ-StRD-Doors-1

REQ-StRD-Doors-2

REQ-StRD-Doors-249

REQ-StRD-Doors-250

NOT OK (X)

OK (√)

REFERENCES

- ✓ Writing Good Technical Requirements in Aviation_ Bengü YAPAR, Dilek KARACA, Engin ÖNCÜL-16th NDIA Systems Engineering Conference
- ✓ Specifying Good Requirements_Donald Firesmith, Journal of Object Technology, 2003
- ✓ Telelogic Presentation
- ✓ INCOSE HandBook

THANK YOU