

Self Protecting Suite for F-16

System Design Description

Case study made at IHA 8/10 2010

System Engineering

Company F

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Index.

1. Scope	3
1.1 Identification.	3
1.2 System overview.....	3
1.3 Document overview.	5
2. Referenced documents.	5
2.1 Documents.....	5
2.2 Standards.....	5
3. System-wide design decisions.	6
3.1 Actors.....	6
3.2 Power On/Off	6
3.3 Mode select	6
3.4 Zerorize.....	7
3.5 Internal Test.....	7
3.6 Thread detected	7
3.7 Program update.....	7
3.8 Plane on ground	7
3.9 Power consumption 28Vdc in pod	7
3.1 Weight	8
3.2 Magazine selector.....	9
3.3 Safety	11
3.4 Security	11
3.5 Handling of navigation data	11
4. System architectural design.	11
4.1 System components.	11
4.2 Concept of execution.....	14
4.3 Interface design.....	19
5. Requirements traceability.	23
6. Notes.	25
6.1 Acronyms and abbreviations.....	25

History

Date	Description	Name	Version
28/9 2010	Document setup made	LMU	0.1
5/10 2010	Paragraph 3 started	KPI	0.2
6/10 2010	Added Power and no selector descriptor	LMU	0.3
7/10 2010	Added Ref doc and acronym	LMU	0.4
7/10 2010	Added component diagram and description + 3.13	KPI	0.5
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1. Scope.

1.1 Identification.

This document describes a self protection suite for the F-16 combat aircraft used by the Royal Danish Air Force. The protection suite incorporates a pod for mounting under the left wing and an intelligent cockpit control unit for controlling the system. In the pod is mounted a Missile Warning System (MWS) which gives input to the cockpit control unit. The cockpit control unit controls the dispensing of flares and chaffs from the pod. The solution shall provide warning upon detection of missile threats and be able to automatically dispense payloads in response.

The MWS will be provided as Government Furnished Equipment (GFE) and be physically installed by Company F.

1.2 System overview.

The system is a self protection suite for a F-16 combat aircraft, and is used to protect the aircraft against missile attacks. The system consists of 2 main systems:

- Cockpit Unit communicates with the systems in the POD and Aircraft Mission Computer, and also has an interface to the aircraft intercom system and an interface for the user to control the system.
- POD holds magazines for flares and chaffs and what is needed for dispensing them, plus the MWS system.

1.3 Document overview.

This document shall describe the Systems Design for the Self Protection System for the F-16 combat aircraft and the implementation of the system shall be based on this document.

This document must only be used in the project group by Company F and the project group and other personal at The Royal Danish Air force that are cleared to have access to this project.

2. Referenced documents.

2.1 Documents

ID	Name	Description
TC1	Terma case.pdf	Document received from TERMA at IHA 3/9 2010
MWS-CD	MWS-CD	Document describing Command and data format for the MWS system.
MOM4	Minutes of meeting Terma SRR meeting at IHA 28_09_10.pdf	
SRS-doc	SRS Missile Warning System ver A.pdf	System Requirement Specification of Self Protecting Suite for F-16.

2.2 Standards

Standard	Description
DM30p	NATO dispenser magazine type contains the complete details about the magazines physical constructions and interface,
FP42f	MIL standard 1600-2-9 v12.45 - F-16 POD standard contains complete specification about requirements for POD manufacturing, including size, weight, material, shape, etc.
FE16d	F-16 EW standard contains the requirements and test procedures required to have a new system approved on an F-16.
PM11b	F-16 POD mounting standard includes specifications on how a POD shall safely be mounted to an F-16 aircraft.
DF14b	NATO threat format specify the protocol to use when exchanging threat data with the F-16 aircraft mission computer.
FBIT12c	F-16 subsystem BIT standard indicate how a subsystem shall test its internal status to comply with the F-16 operational standard.
ACTv2	Separate document excluded due to the fact that it is not important for the process.
AMM32f	Aircraft maintenance manual contains details about how removable parts on aircraft shall be located and labeled.
SDS23v	DOD sensitive data standard specify how sensitive data must be stored, and also how the decryption key must be stored.
DWS12g	DOD data wipe specification dictates how sensitive data must be wiped from different media.

MIL-1553B	Military standard for a redundant communication protocol. The MIL-1553B is pure master-slave(s), and can have 1 Bus Controller (BC) and a number of Remote Terminals (RT). Only the BC can initiate communication, so if two RTs are to communicate it must be programmed into the BC. The MIL-1553B specify polling frequencies of up to 50Hz, meaning that a given package (e.g. status information) can be requested (and thereby sent) with a minimum interval of 20ms.
FAI134g	F-16 Audio Interface for Intercom

3. System-wide design decisions.

3.1 Actors

This paragraph lists all actors who will be using the system. An actor can be anything which creates an input event to the system e.g. a person, a machine or a signal. In the list below, actors are preceded with the stereotype <Actor> and then followed by a brief description.

<Actor> **Pilot.**

The pilot will use the system from an operational point of view.

<Actor> **Service.**

Service is service personnel who maintains the system, perform test on the system etc.

<Actor> **ECU.**

The Electronic Control Unit is an electronic device providing information from the pod.

<Actor> **AMC.**

The Aircraft Mission Computer provides info from the aircraft system.

<Actor> **Zerorize.**

Zerorize is an electrical signal.

<Actor> **System.**

The system itself can initiate actions.

<Actor> **TestSystem.**

The test system can program, download configuration files and perform test sequences.

3.2 Power On/Off

Actors: <Actor> **Pilot**; <Actor> **Service**

When the CCU is powered on it will initialize itself and run a selftest. After initialization and selftest it will power up the rest of the system and then enter standby state.

If plane on ground signal is off, the state will change to armed state.

3.3 Mode select

<Actor> **Pilot**; <Actor> **Service**

Mode select has only effect in armed state. When state changes from not armed to armed the system will enter an armed internal state (manual, semi automatic, automatic) depending on the position of mode select.

3.4 Zerorize

<Actor> **Zerorize.**

This is handled under security.

3.5 Internal Test

<Actor> **Service**, <Actor> **System**.

The internal test is initiated by the system every 15 minutes. The test can also be initiated by ground personnel.

3.6 Thread detected

<Actor> **ECU**.

When the system is acknowledge about a missile attack from the MWS, the system will display the direction of the thread in body frame format on the AMC within 20ms and initiate an audible sound on the intercom within 20ms.

3.7 Program update

<Actor> **TestSystem**; <Actor> **Service**

The system software can be updated via a connector on the CCU. When the connector is plugged in the system can be reset by an external system. The external system can load new software or a new configuration file into the system.

3.8 Plane on ground

<Actor> **AMC**

When the aircraft is on ground the plane on ground signal is active low so that the system cannot be armed by a defect wire.

3.9 Power consumption 28Vdc in pod

The PCU used to convert from 115Vac to 28Vdc in the pod can as maximum deliver 250W. At the same time UR-20 in the document TC1 required dispensing 2 payloads at the same time, but looking on the power analyse below:

Dispensing 2 payloads at the same time.

Tabel 1

	Number	Consumption 28Vdc [W]	Consumption 115Vac [W]	Total for components@28Vdc [W]	Total for components@115Vac [W]
ECU	1	85	100	85	100
DSS's	4	3	0	12	0

Dispensing	2	126	0	252	0
Total				349	100
Total Power consumption from 28Vdc and 115Vac					449

Shows that the power consumption on the 28Vdc in the pod is above 250W.

When reducing to only dispense 1 payload each time reduce power consumption to:

Tabel 2

	Number	Consumption 28Vdc [W]	Consumption 115Vac [W]	Total for components @28Vdc [W]	Total for components @115Vac [W]
ECU	1	85	100	85	100
DSS's	4	3	0	12	0
Dispensing	1	126	0	126	0
Total				223	100
Total Power consumption from 28Vdc and 115Vac					323

223W is well below the maximum of 250W.

UR-20 was by agreement with Terma at SRR meeting at IHA changed to SR-53 in SRS-doc, see MOM4, which says that the system shall be able to dispense 2 payloads in 40msec. By changing it to this requirement reduced the power use on the 28Vdc to 223W, well below the 250W.

3.1 Weight

SR-74 in the SRS-doc states that the maximum allowed weight of the pod is 270kg. Below is a table with the weight of the different items.

	Number of items	Weight per item	Total/item type	
pod harness	1	20	20	kg
pod structure	1	175	175	kg
PCU	1	25	25	kg
ECU	1	18,2	18,2	kg
4 x DSS	4	5	20	kg
4 x Dispenser	4	3	12	kg
Total			270,2	kg

The total is 0,2 kg above the maximum of 270kg, but it were agreed on the SRR meeting at IHA that up to 10kg was allowed, see MOM4. So it is decided to keep this construction, which allows us to use known components that aren't changed due to a demand for lower weight – a more safe solution.

3.2 Magazine selector

Each DSS can control 2 magazines and it is possible to add a control line that could select between the 2 magazines. But there are no requirements on this part of the system, so the system design sketched below show no selector for selecting magazine 1 or 2. The decision is to leave out the selector signal and the reasons for leaving out the selector signal are:

- No requirements state anything about the ability the select magazine 1 or 2.
- No requirements require that only Chaffs or flares shall be dispensed.
- Leaving out the selector make it a more simple system with less timing issues.

So when a DSS get the order to dispense it will start with the first payload in magazine 1, then the second one and it will continue so until every payloads in magazine 1 is used. After all payloads in magazine 1 are used then it will dispense the first payload in magazine 2 and continue so until the last payload in magazine 2 is used.

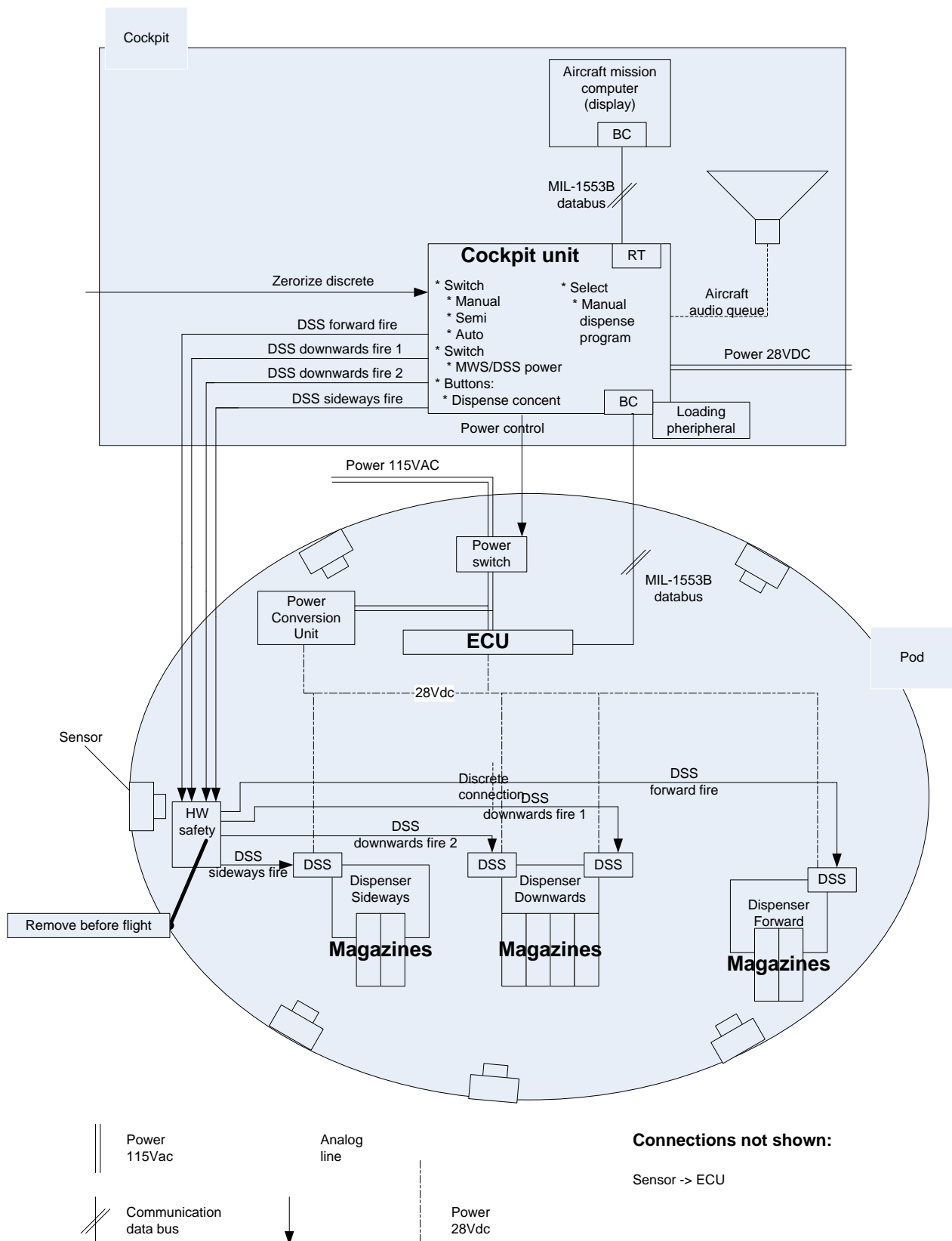


Figure 2 Block diagram of system

3.3 Safety

To prevent that chaffs or flares can be fired at times where it can be dangerous to other users, ground personal and other people or things in the surroundings, a hardware safety switch is build into the system. This safety switch prevent that the DSS' get a firing signal for any chaffs or flares as long as the safety switch is activated. Further more the CCU is always monitoring the "Plane On Ground" signal which is received as data on the bus from the AMC and as long this signal is logical high, indicating the plane is not in the air the CCU may not give a signal for firing chaffs or flares even though the MWS gives a missile warning.

3.4 Security

For security reasons the CCU is monitoring a zeroize signal from the aircraft, and if this signal goes logical high the self protection suite shall erase sensitive data in the system. If the signal goes to a high level the CCU will send a zeroize signal to the ECU in the MWS to start the erasure of sensitive data there and also start to erase its own sensitive data.

3.5 Handling of navigation data

The CCU shall be able to convert navigation data in body frame format to inertial data and back again. It is not stated in the requirements how fast this shall be done, but in order to calculate the speed of a missile this must be done within 40 ms.

4. System architectural design.

In the following paragraphs the system architectural design are described.

4.1 System components.

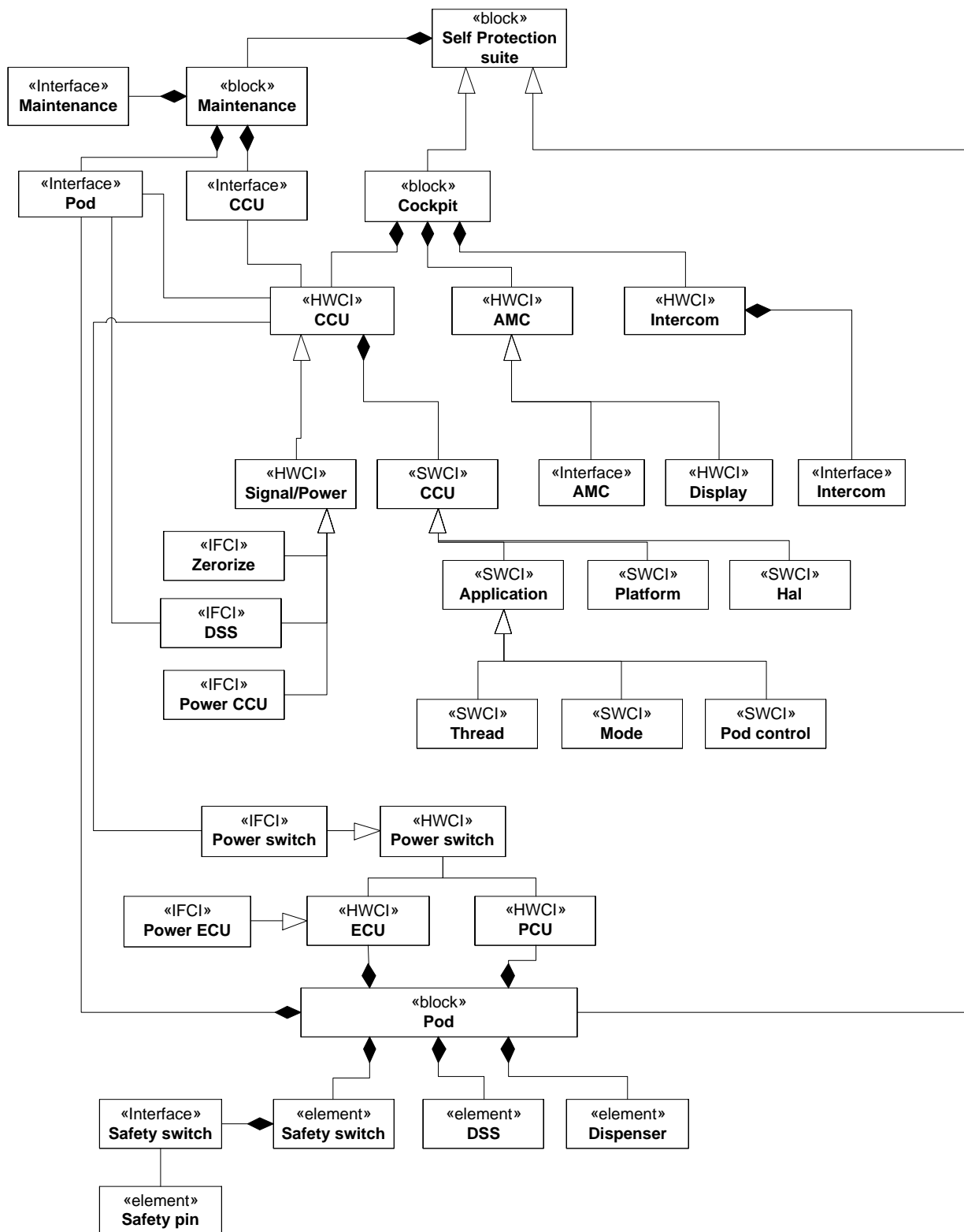


Figure 1 Component diagram

Tabel 3 Component ID's for components in figur 3

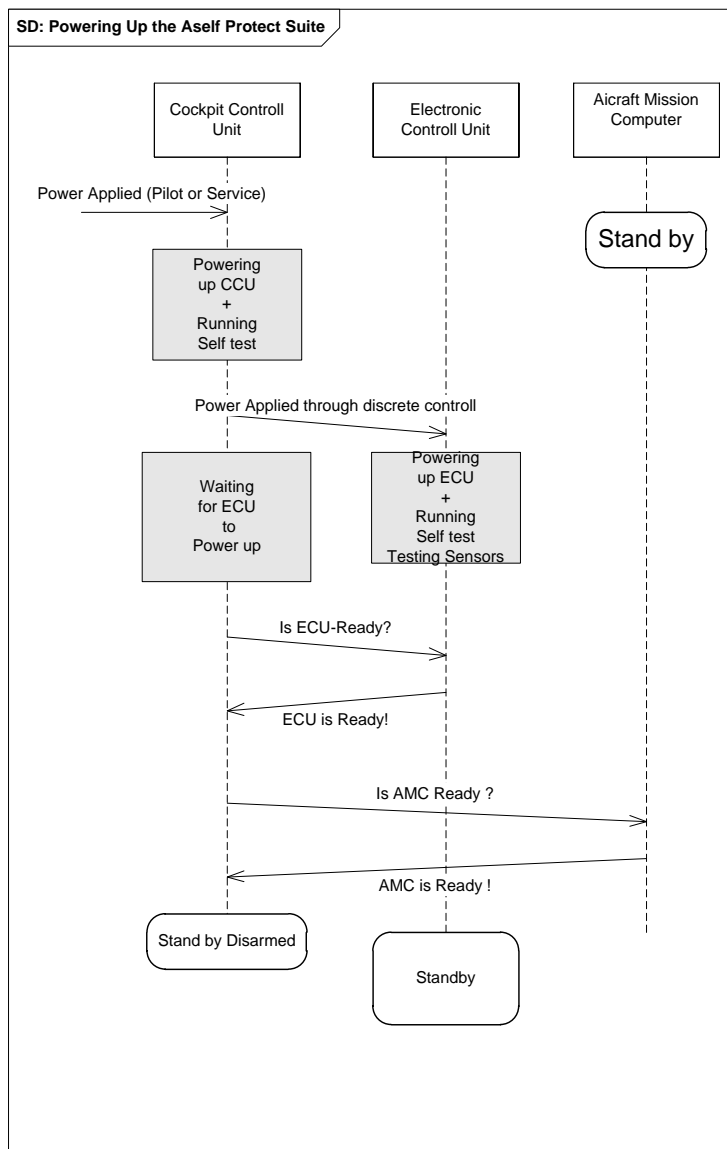
Component ID	Component name	Description	Design decision
IFCI001	Maintenance	Maintenance interface for service personnel	Internal test Program update
B001	Maintenance	Maintenance connections to the self protection suite	Program update
IFCI002	CCU	Interface specification for CCU	Internal test Program update
HWCI002	CCU	CCU electronics, connectors and enclosure	
SWCI001	CCU	Software block for CCU	
SWCI002	Application	Software component includes all applications.	Thread detected Mode select Internal test Magazine selector
SWCI003	Platform	Software component to handle scheduler/timers/keys etc.	Plane on ground Zerorize Thread detected Mode select Internal test Magazine selector
SWCI004	Hal	Hardware application layer. Software component which decouples hw from sw.	
SWCI005	Thread	Application which handles incoming missile attacks.	Thread detected Magazine selector
SWCI006	Mode	Application to handle mode requests	Mode select
SWCI007	Pod control	Application to handle setup and communication with MWS	Handling of navigation data
IFCI003	AMC	Aircraft mission computer interface specification	Thread detected Internal test
HWCI003	AMC	Aircraft mission computer block	
IFCI004	Intercom	Intercom interface specification	Thread detected
HWCI004	Intercom	Intercom handling audio	Thread detected
HWCI005	Signal	Hardware block with connections for all discrete signals	Plane on ground Zerorize Magazine selector Thread detected Security
HWCI006	Display	Aircraft mission computer display for displaying information and thread warnings from the CCU	Thread detected
HWCI007	Power switch	Power switch for enabling MWS	Power on/off
HWCI008	ECU	ECU block	
HWCI009	PCU	Power conversion unit. converting 115Vac to 28Vdc for DSSs and ECU.	
IFCI005	Pod	Interface provided by the pod incl. Communication bus, discrete	Thread detected

		signals	
B002	Pod	Pod block	
IFCI006	Safety switch	Interface specification for safety switch	Safety
E001	Safety Pin	Safety pin to operate safety switch	Safety
E002	Safety switch	Safety switch for power cut-off to DSS	Safety
IFCI007	Zerorize	Erase memory	Zerorize Security
IFCI008	DSS	Interface to DSS	
IFCI009	Power CCU	Interface for CCU power	
IFCI010	Power ECU	Interface for ECU power	
E003	DSS	Digital sequenser switches	
IFCI011	Power switch	Interface for control of power switch	

4.2 Concept of execution.

Powering up the System

When the Cockpit Control Unit is powered on it will initialize itself and run a selftest. After initialization and selftest it will power up the rest of the system and then enter standby

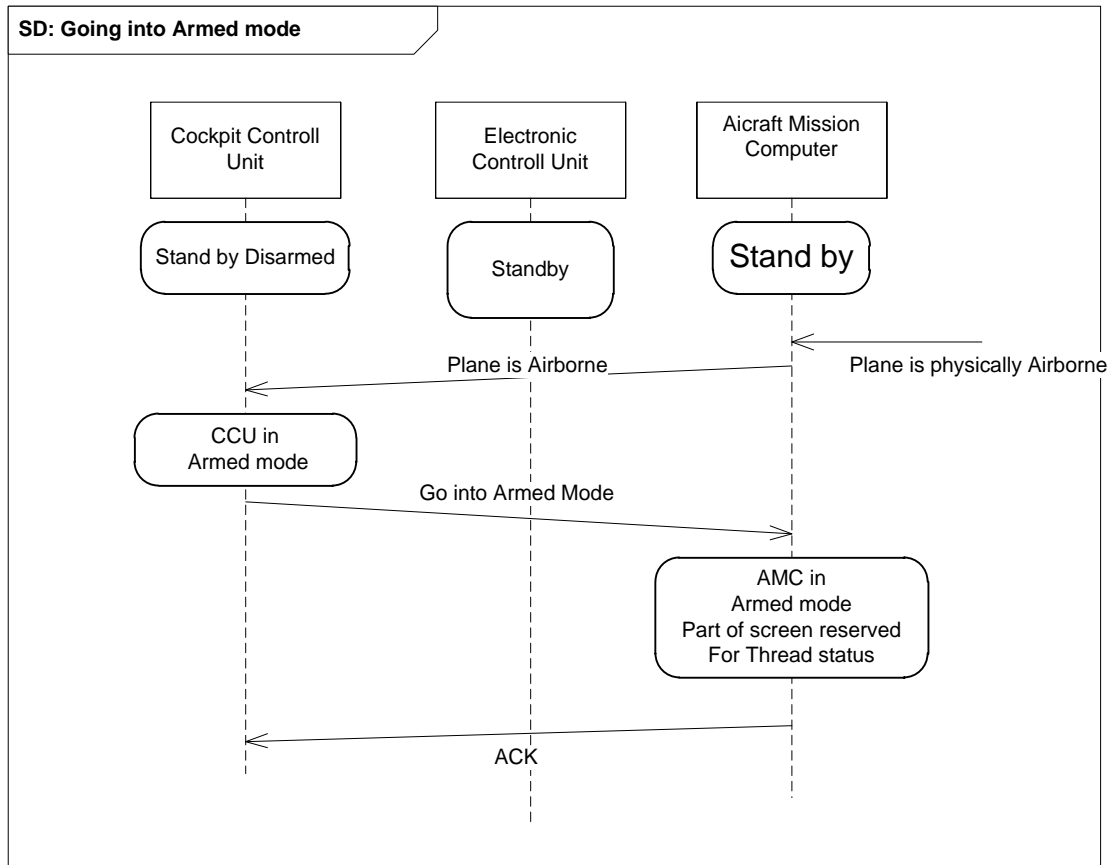


state.

Figur 4 Example of typical Powerup sequence

Arming of the system

Arming of the system is done when the plane is airborne AND the safetypin is removed

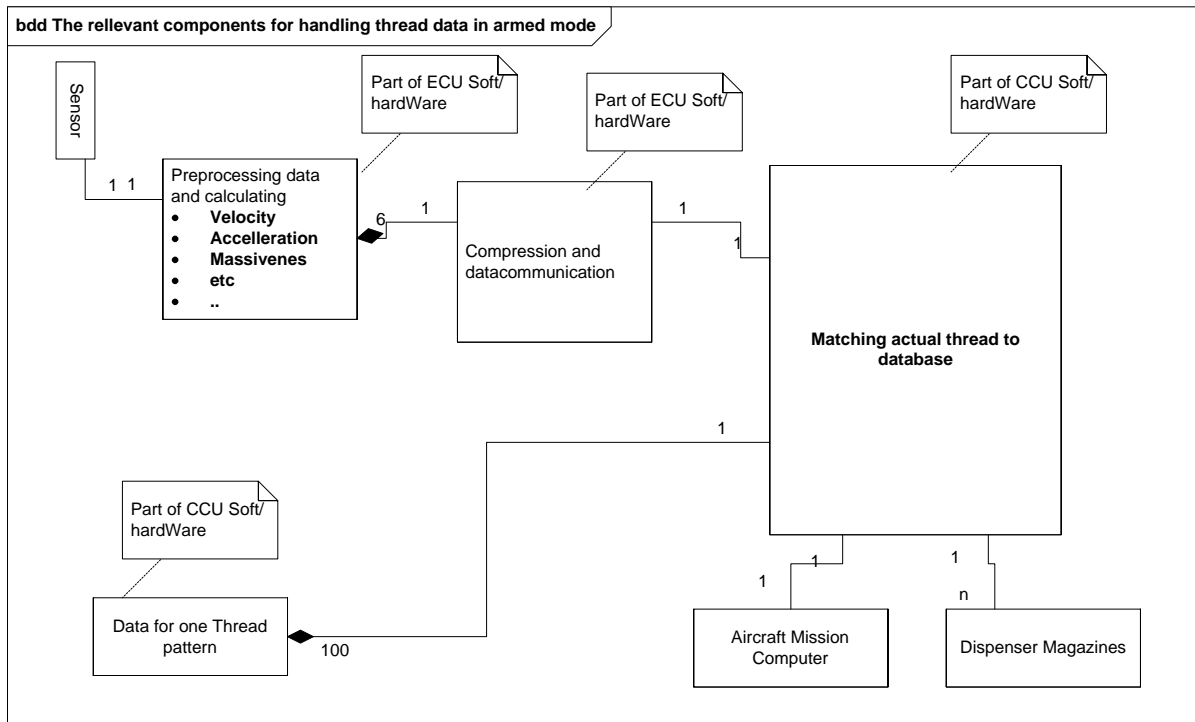


Figur 5 Typical sequence showing how to go into armed mode

Calculating Thread pattern and matching thread pattern

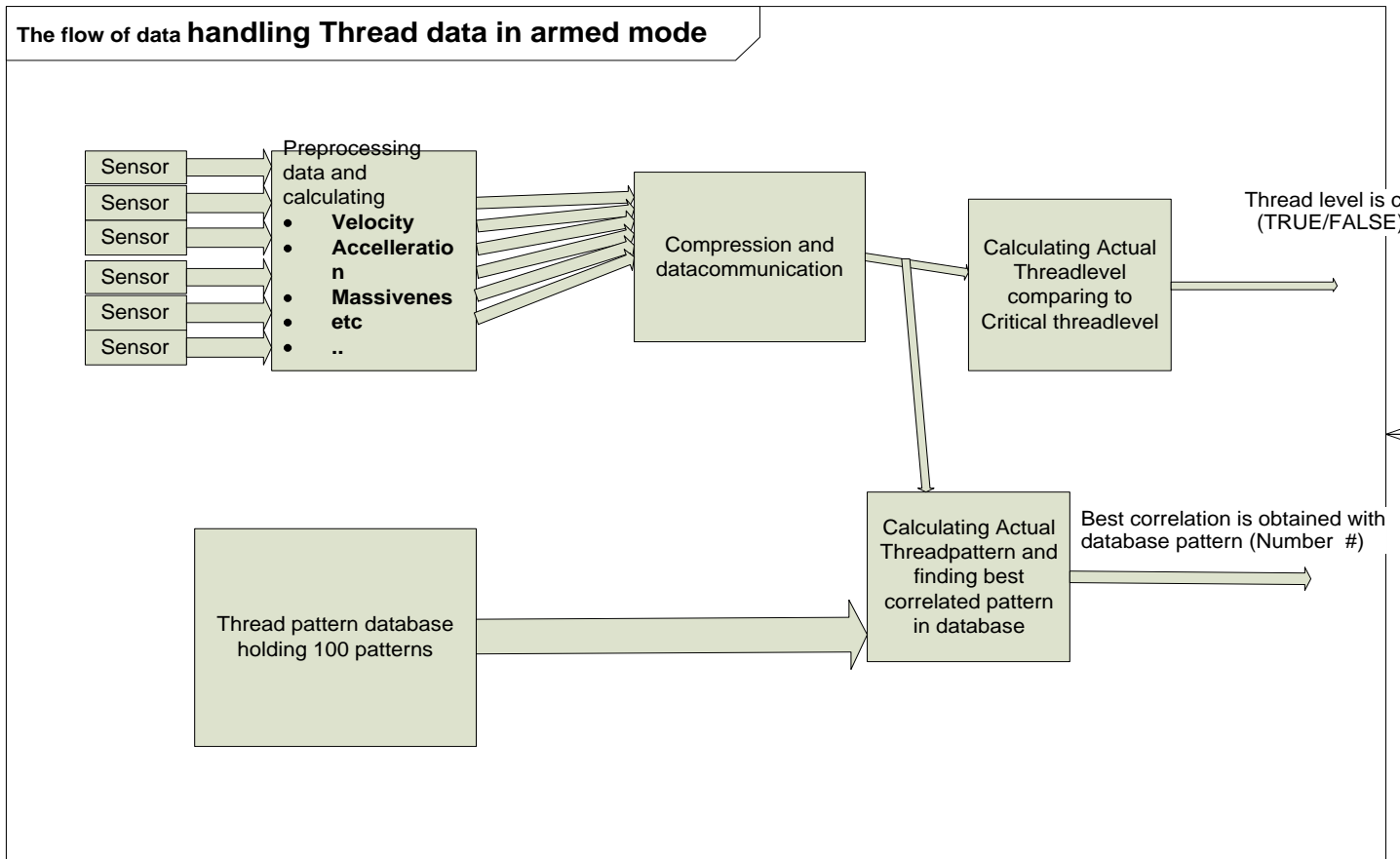
When CCU is in armed mode it goes into a process continuously calculating a number of aspects in the actual thread status and decides

- If the actual thread pattern level is above the critical Thread pattern
- What thread pattern from database correlates best to the actual thread pattern



Figur 6

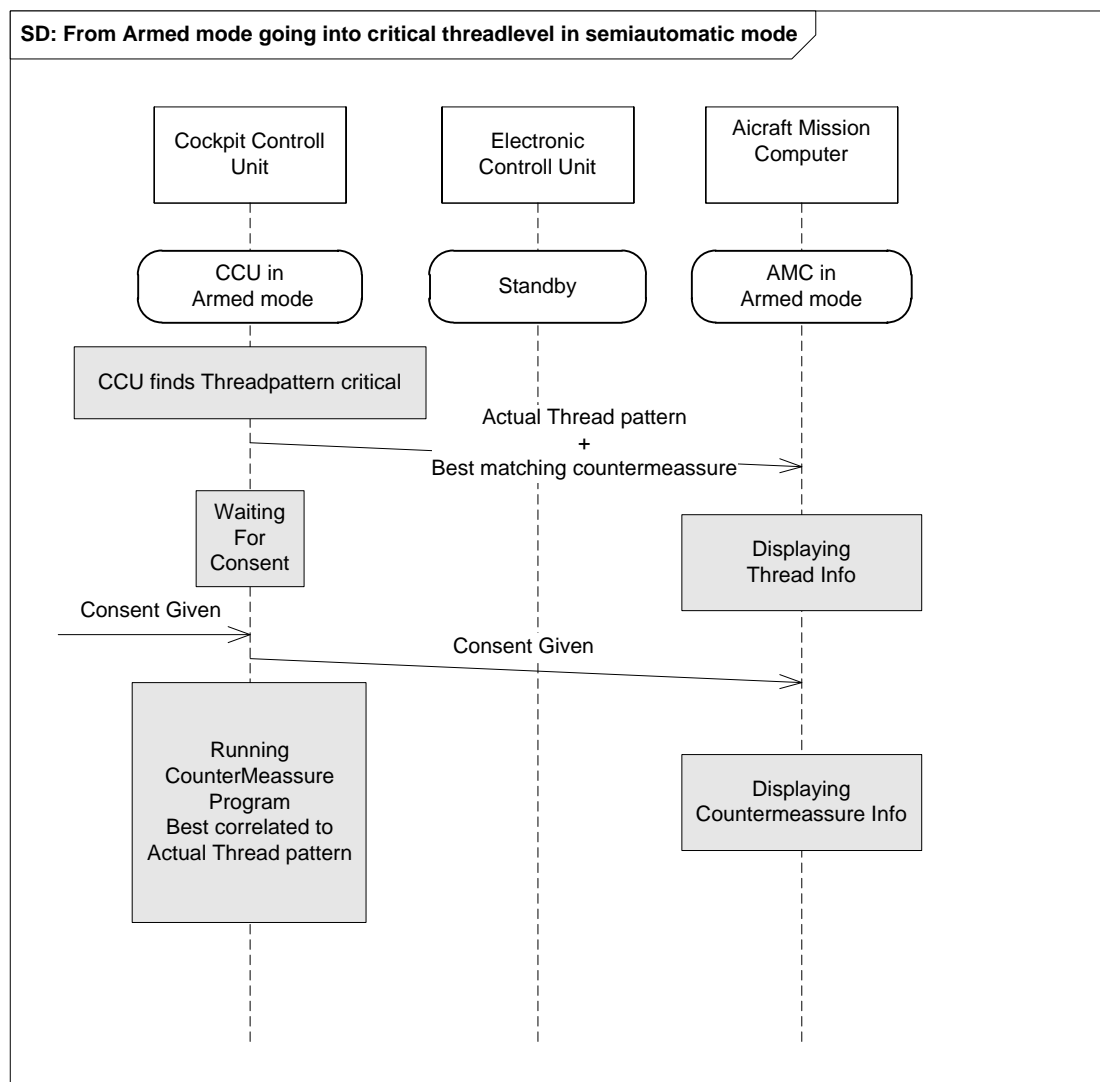
The flow of data when handling Thread data in armed mode is shown below.



Figur 7

Entering Critical Thread pattern

When Threadlevel is critical the behavior will be different depending on the mode automatic semiautomatic or manual.



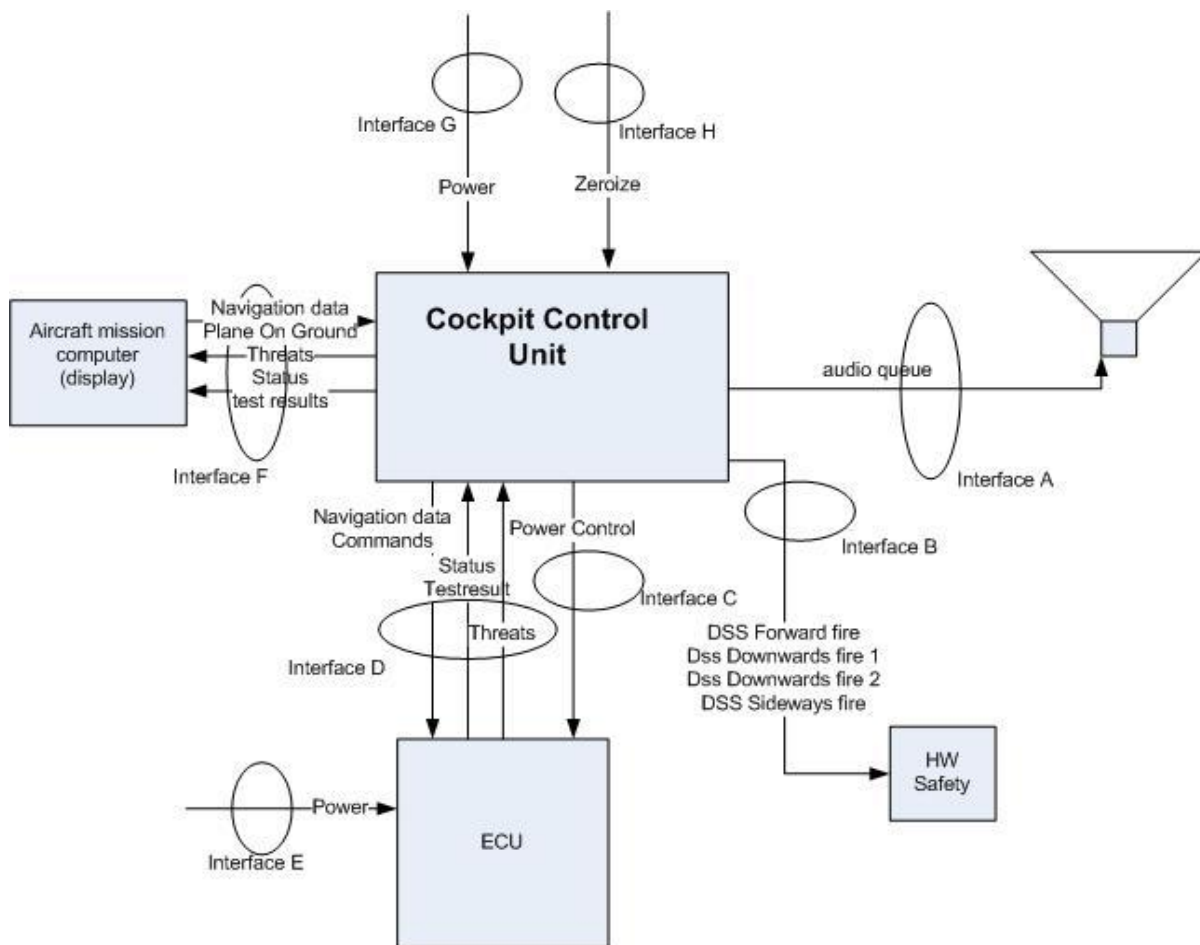
Figur 8

4.3 Interface design.

In the following subparagraphs are the interfaces of systems components described.

4.3.1 Interface identification and diagrams.

The system has a number interfaces, some internal, some external, some mechanical and some are software interfaces. Below is a sketch showing some the interfaces. The mechanical interface used to mount the pod on the wing and software interfaces are not shown here.



Figur 9- Interface A, E, F G and H are interfaces to external parts/systems.

4.3.2 Interface A (IFCI009 CCU to Aircraft Intercom).

To interface the Cockpit Control Unit to the aircraft intercom system the interface will follow the interface described in audio interface for intercom in the F16: FAI-34G.

4.3.3 Interface B (IFCI008/IFCI006 CCU to Safety Switch).

Between the cockpit control unit and the pod there are 6 discrete wires, used for various signals:

- 4 of them for controlling the firing chaffs and flares using the 4 DSS'. Logical high is firing command. Pins used:
 - o No 1: DSS Forward fire
 - o No 2: DSS Downward fire 1
 - o No 3: DSS Downward fire 2
 - o No 4: DSS Backward fire
- 1 for controlling the power switch in pod. Logical High level Power Switch ON
 - o No 5: Power Switch

- 1 is a spare wire.
- No 6: Spare

At the Cockpit control unit is used an EDWC7f connector for the discrete wires, the same connector is used at the pod.

4.3.4 Interface C (IFCI011 CCU to Power Switch in pod).

To control the power in the pod there is a controllable power switch in the pod. Through interface C this control signal is feed from Cockpit Control Unit to the power switch. Connections, connector and levels are described in [Interface B \(Cockpit Control Unit to Safety Switch\)](#). as the two interfaces use the same connector.

4.3.5 Interface D (IFCI005 CCU to ECU).

This interface is used for the communication between the CCU and ECU. Communication is done via the MIL-1553B data bus which defines signal levels, baud rate, data bit and every other parameter needed for setting up the communication on a MIL-1553B data bus. Connector used is an EDC29b connector.

Data on the bus will be command and data for controlling the MWS and getting data from it. Commands and data formats are described in the MWS-CD document and will not be described further here. Data and commands that shall be sent to the ECU are:

- Aircraft attitude.
- Aircraft Heading.
- Aircraft altitude.
- GPS data.
- Commands for starting ECU Built in self test.

The ECU will the other way make it possible for the CCU to get:

- Status information each 20msec.
- Result of Built in self test .
- Thread information in inertial format.

4.3.6 Interface E (IFCI010 Power to Power Switch in pod).

To be able to control the power to the pod a controllable power switch in the pod is mounted. Power from the supply in the wing is connected to this power switch through the connector mounted by subcontractor on the pod and not as indicated to the ECU. This wiring is done by the subcontractor which makes the total harness for the pod, so it will not be described further here.

4.3.7 Interface F (IFCI003 CCU to AMC).

This interface shall make it possible to communicate with the AMC. Information will both be from AMC to the CCU and from the CCU to the AMC. Communication is done via the MIL-1553B data bus which defines signal levels, baud rate, data bit and every other parameter needed for setting up the communication on a MIL-1553B data bus. Connector used is an EDC29b connector.

Data on the bus will be command and data for the status and data communication. Commands and data formats are described in the DF14b which specify the protocol for exchanging threat data with AMC. Data and commands that shall be sent to the CCU are:

- Aircraft attitude.
- Aircraft Heading.
- Aircraft altitude.
- GPS data.
- Commands for starting CCU Built in self test.
- Plane On Ground signal.

The CCU will the other way make it possible for the AMC to get:

- Status information.
- Result of Built in self test.
- Thread information in body frame format.

4.3.8 Interface G (IFCI009 Power to CCU).

The Cockpit Control Unit will be supplied with 28VDC from the aircraft. An EDC22b connector will be used, pin numbers used are:

- No 1: +28Vdc
- No 2: 0Vdc

4.3.9 Interface H (IFCI007 Zeroize to CCU).

The Cockpit CCU will be given a discrete signal from aircraft. An EDC21b connector will be used, pin no 1 is for the Zeroize signal. A Logical High level of 5V defines zeroize sensitive data. Further description of zeroize can be found in the paragraph about [Security](#).

4.3.10 Mechanical interface, pod to wing

The pod has a mechanical interface to the left wing and it will be mounted with standard T hooks spaces with 13 inches.

5. Requirements traceability.

In the table below is it possible to trace between System Components and the SR's from the "SRS Missile Warning System ver A.pdf" (SRS-doc) and the column with the text Trace ID is back to the "Terma Case.pdf" (TC1) received at IHA.

REQ ID	Trace ID	AMC	CCU	Safety Switch	Safety Pin	Aircraft Intercom	Power Switch	Pod	DSS	Dispenser	PCU	ECU
SR-1	UR-8		X	x	X							
SR-2	UR-8 indirect		X									
SR-3	UR-8 indirect		X	x	X							
SR-4	UR-8 indirect		x	x	X							
SR-5	UR-12		X									
SR-6	UR-12 indirect		X									
SR-7	UR-12 indirect		X									
SR-8	UR-12 indirect		X	x	x							
SR-9	UR-11		X				x					
SR-10	UR-11 indirect		X				x		x	x	x	x
SR-11	UR-11 Indirect		X				x		x	x	x	x
SR-12	UR-21		X									
SR-13	UR-21		X									
SR-14	UR-15		X									
SR-15	UR-16		X									
SR-16	UR-5	x	x									
SR-17	UR-7		X			x						
SR-18	UR-7		X			x						
SR-19	UR-7		x			X						
SR-20	UR-13		X									
SR-21	UR-14		x									
SR-22	UR-7		x									x
SR-23	UR-14		x									

SR-24	UR-15		x									
SR-25	UR-3		x	x	x		x	x	X	x	x	x
SR-26	UR-10		X									
SR-27	UR-6		x									x
SR-33	UR-2		x									X
SR-34	UR-2							X		x		
SR-35	UR-2							x		X		
SR-36	UR-1							X		X		
SR-37	UR-2							X		X		
SR-38	UR-2							X		X		
SR-39	UR-1							X		X		
SR-40	UR-2							X		X		
SR-41	UR-1							X		x		
SR-42	UR-3							X				
SR-43	By fault left out in SRS-doc											
SR-44	UR-6		x									x
SR-45	UR-6		X									x
SR-46	UR-10											x
SR-47	UR-3											x
SR-48	UR-5		X									
SR-49	UR-6		X									x
SR-50	UR-6		X									
SR-51	UR-6		x									
SR-52	UR-9		X									
SR-53	UR-20		x				x		x	x	X	
Left blank by fault in SRS- doc	UR-7		x			X						
SR-54	UR-40	X	x									
SR-55	UR-5		X									
SR-56	UR-5		X									
SR-57	UR-9		x									
SR-58	UR-40		x									X
SR-59	UR-5		X									x
SR-60	UR-10		x									X
SR-61	UR-8			x	X							
SR-62	UR-8				X							
SR-63	UR-9		X									x
SR-64	UR-9		X									
SR-65	UR-9		X									

SR-66	UR-9		X									
SR-67	UR-32							X				
SR-68	UR-33							X				
SR-69								X	x	x	x	x
SR-70	UR-30							X				
SR-71	UR-30							X				
SR-72	UR-30							X				
SR-73	UR-30							X				
SR-74	UR-31				x	x		x	x	x	x	x
SR-75								X				
SR-76	UR-42							X				
SR-77	UR-4							X				
SR-78	UR-1							x		X		
SR-79												X
SR-80												X
SR-81			X									
SR-82	UR-43						x		x	x	x	x
SR-83							x				x	x
SR-84							x				x	x
SR-85									x	x	x	
SR-86	UR-22							x				

6. Notes.

6.1 Acronyms and abbreviations

AMC	Aircraft Mission Computer
CCU	Cockpit Control Unit
DSS	Digital Sequencer Switches
ECU	Electronic Control Unit, part of MWS
GFE	Government Furnished Equipment.
HWCI	Hardware configuration item
IFCI	Interface configuration item
MWS	Missile Warning System
SWCI	Software configuration item
AMC	Aircraft Mission Computer
CCU	Cockpit Control Unit
DSS	Digital Sequencer Switches
ECU	Electronic Control Unit, part of MWS
GFE	Government Furnished Equipment.
MWS	Missile Warning System