Ladybird Guide to Spacecraft Operations: Book 1 Introduction

Presented by

DAVID EVANS

ESOC/ESA OPS-OSA

The ladybird guides

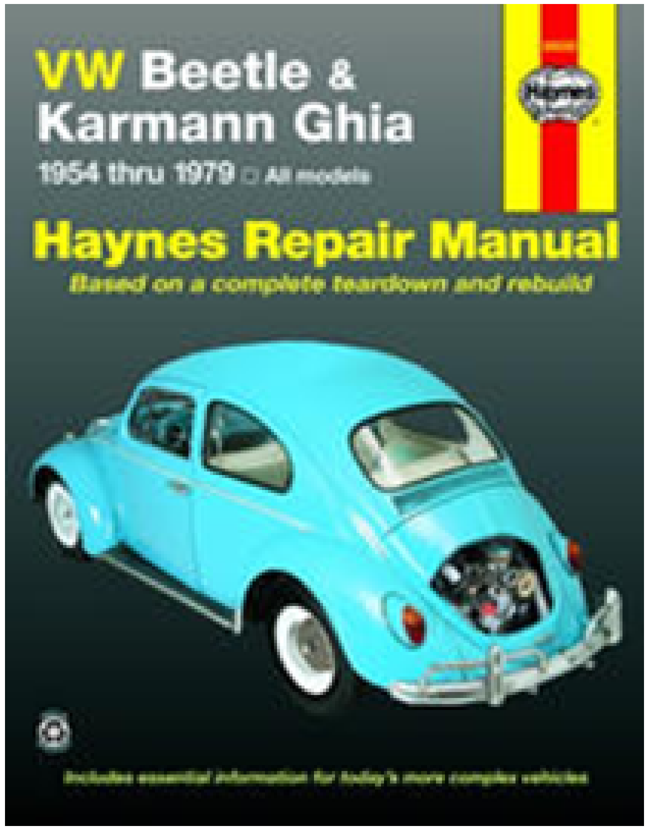
Day One

Day 1: Introduction, missions and payloads

Objectives:
To appreciate the unique nature of being an operator
To be able to describe the end to end mission design process
To understand where operations fits in that process
To understand the concept of spacecraft buses and payload

1. Introduction
2. Why is operating a spacecraft different than building one?
3. How mission goals lead to the mission requirements
4. How mission requirements drive the payload design
5. An example payload: Telecommunications Payload Module
6. How payload design drives the spacecraft design
7. Standard spacecraft buses: Trucks and Trailers
8. The different subsystem functions

What is this?



John Haynes wrote and published his first manual while he was still at school in 1956.

Now the company sells 7 million manuals per year.

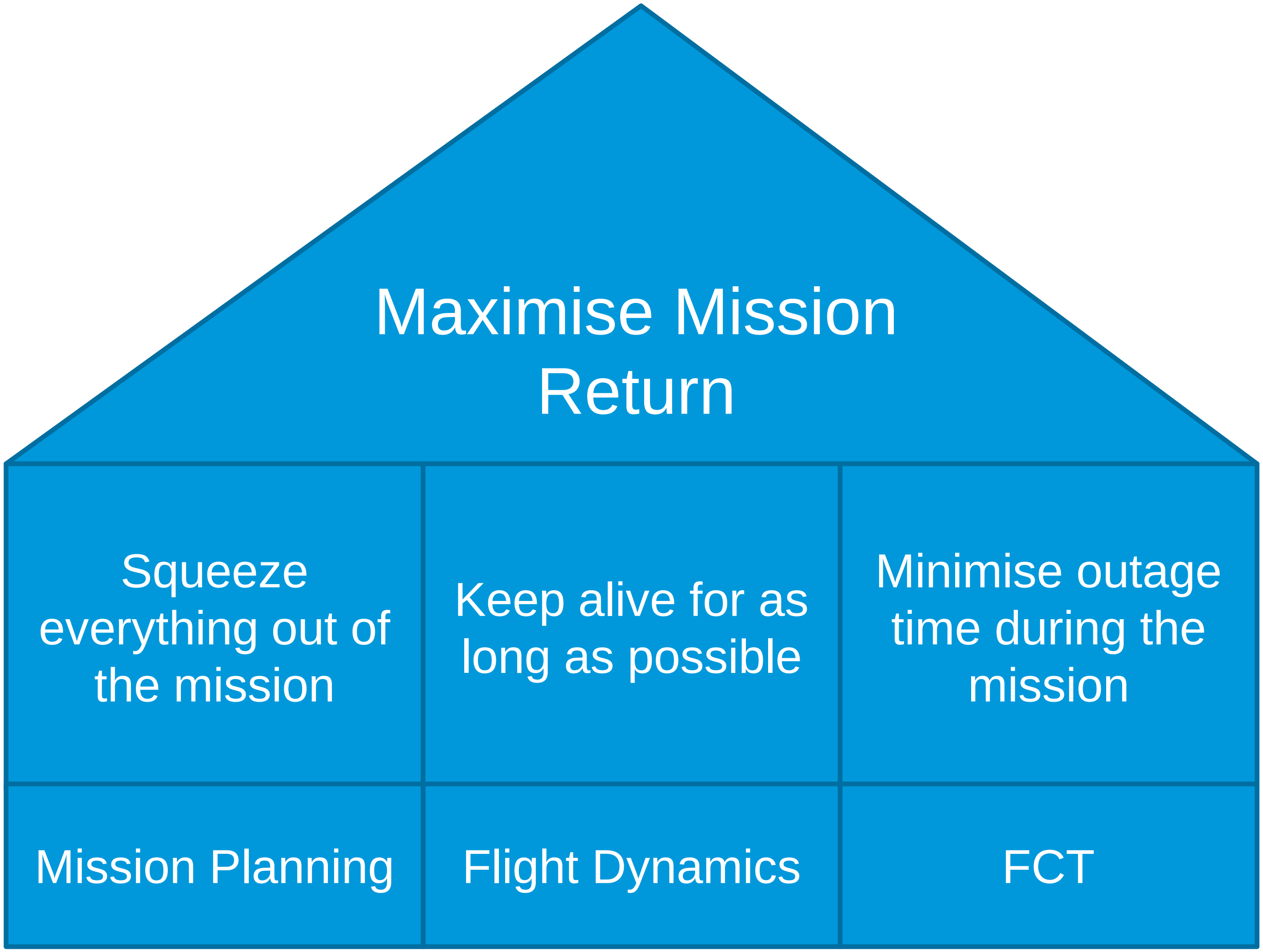
The operations game

The skills and knowledge required to operate, repair and modify a system are different from those required to build one.

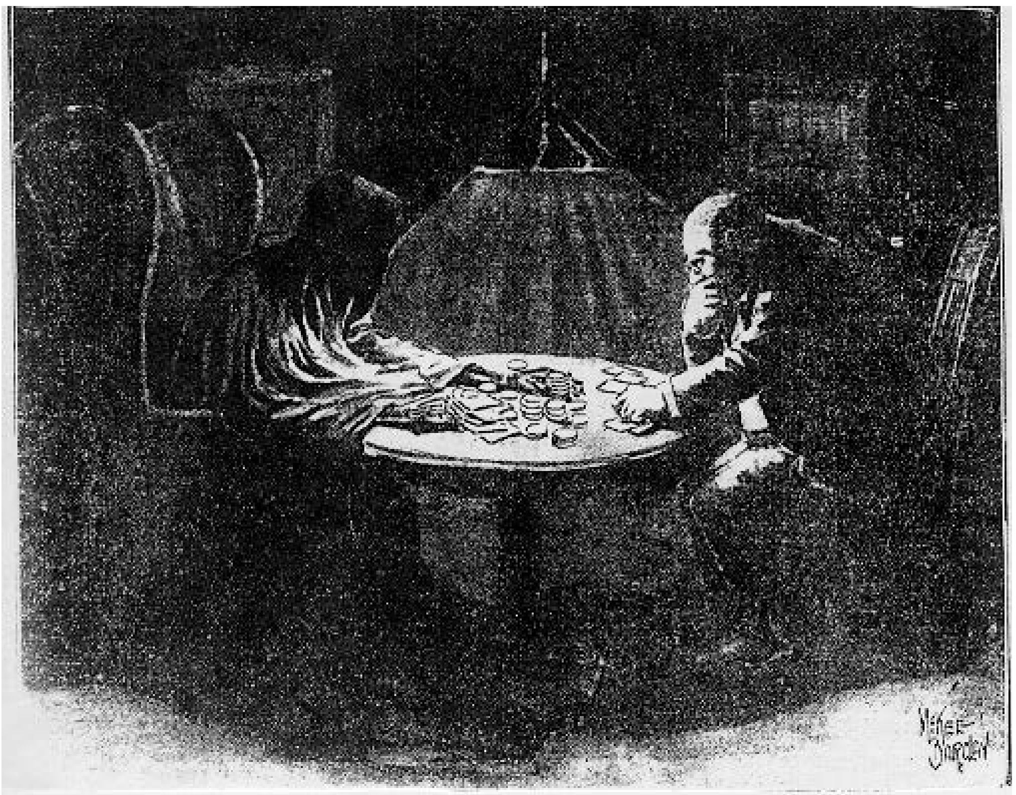
For example, to play the operations game you must understand everything at the conceptual level...

but you do not have the time to understand any one subject at a deep level.

So what's the operations game?



Who is our opponent?



Do not underestimate him

Do not expect him to show you any mercy when you make mistakes

Always remember that space, even more than air and sea is the most unforgiving environment in which to play him

How to become a good player

Understand all the game pieces and how they fit together

Fate loves black boxes and unclear interfaces

Practice the game: Use your imagination, play Fate's role

A clever man learns from his mistakes

A wise man learns from the mistakes of others

A good operator learns from his near and actual mistakes, from others' near and actual mistakes and all the mistakes he made in his imagination first

Play the game defensively: stacking the odds in your favour

Defensive does not mean being rigid or cowardly – quite the opposite.

Often you need to adapt rapidly to new risks / opportunities & this takes courage.

Fate loves operators that do not adapt – i.e. "blind" procedure followers.

Read this

“The Black Swan” by Nassim Taleb 2007

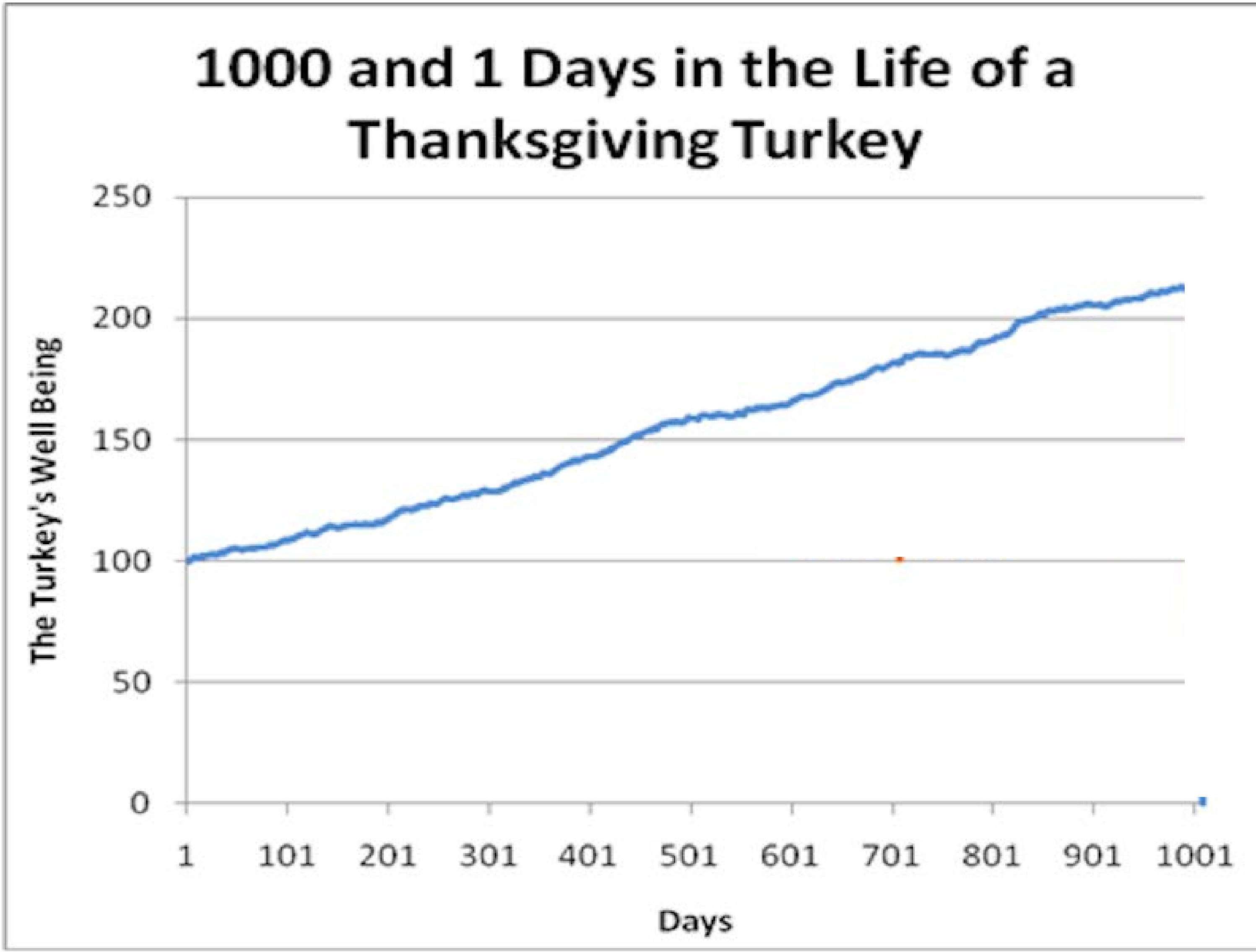
Know the traps

TRAP	SOLUTION
Narrative Fallacy	Listen to the right stories
Belief Inertia	Remain Agnostic
Confirmation Bias	Learn to Negate
Ludic Fallacy	Question Assumptions
Personification	Just Do Not

https://www.youtube.com/watch?v=vKA4w2O61Xo

Meet the Turkey

Learn from the turkey



Do not be a turkey

There is little information in normal behaviour. It can make you feel safe when you are not.
Why?

We respect what has happened not what <u>might</u> have happened. This is much harder to see.
How do we get better at this?

What you don't know is often more relevant than what you do know.
What can we do about it?

If you want to know something about someone or something, you have to watch it in extreme circumstances.
How?

Society makes heroes of rescuers but not of preventers.
Why?

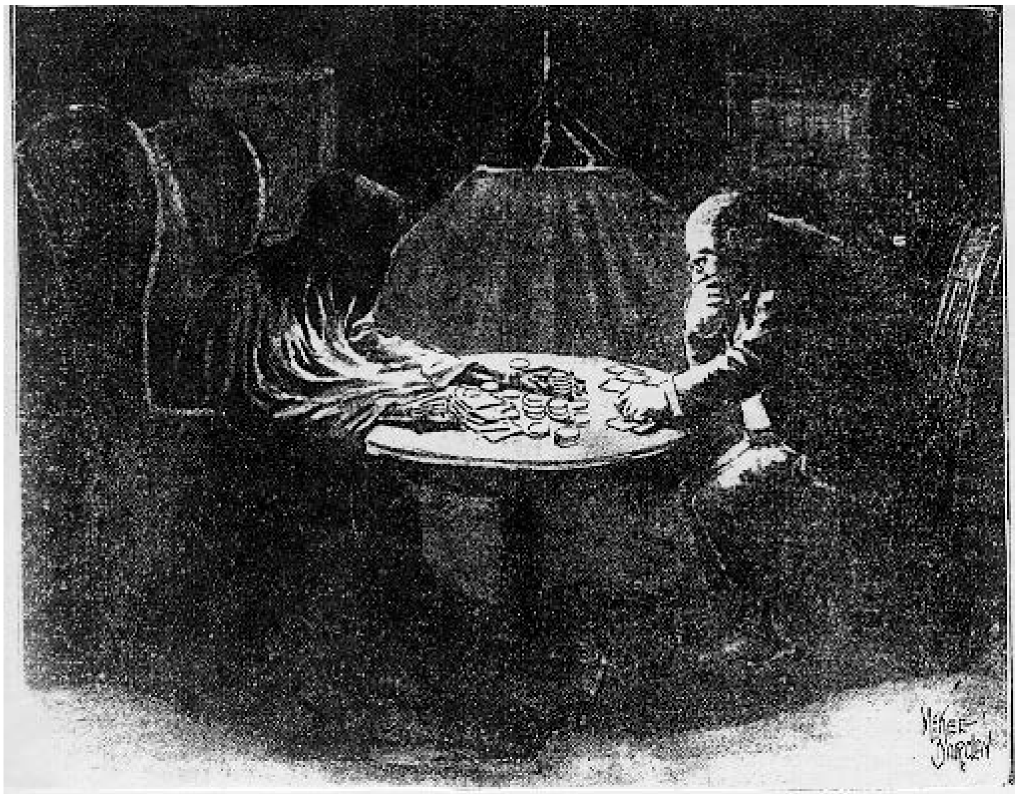
Do not be a turkey

Operators train themselves to imagine what could have happened or might happen in the future

Then they constantly rearrange their systems to prevent bad things happening or to be prepared for them if they do

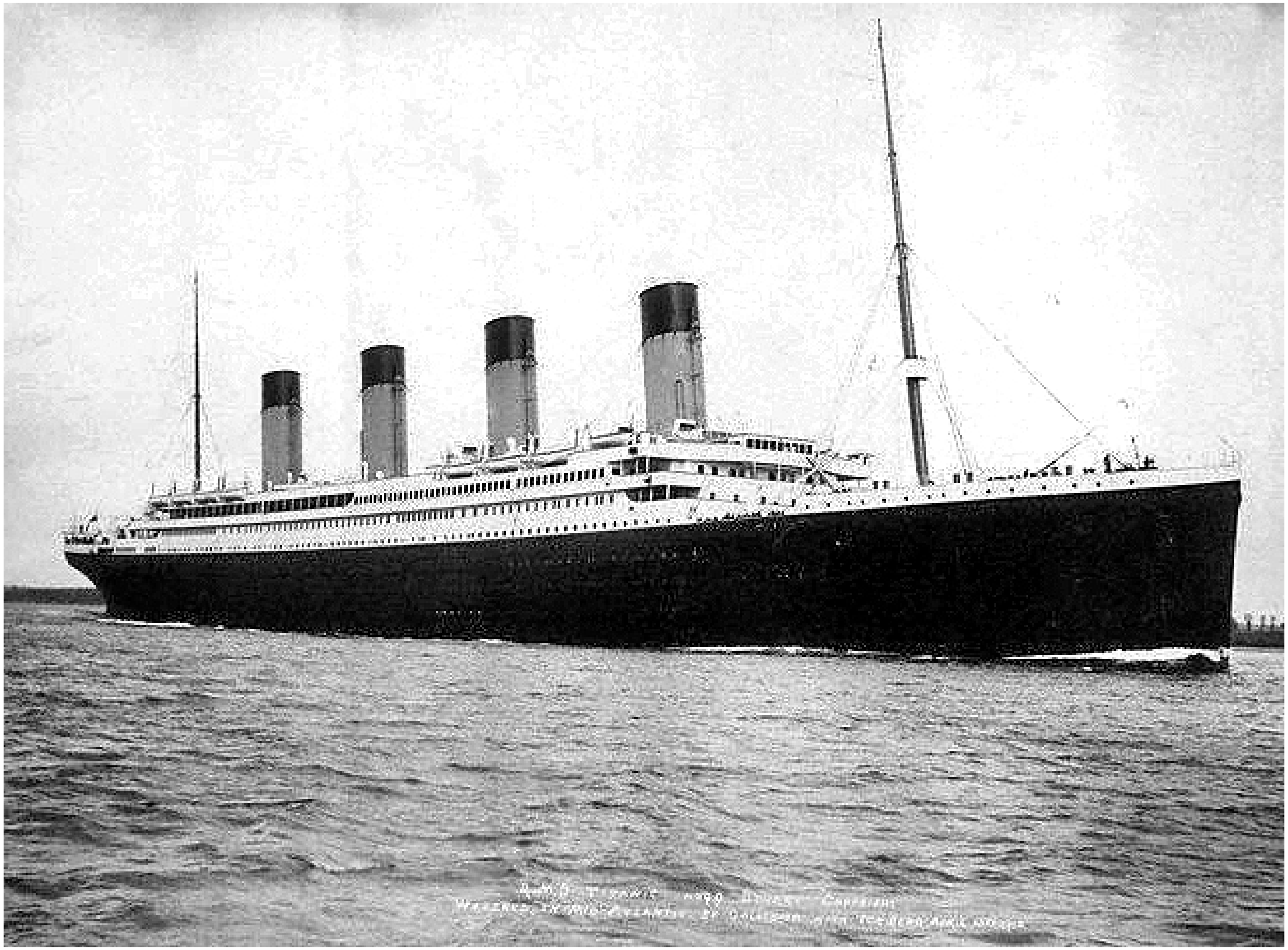
Turkeys are not good operators…

A quiz



Baltimore Morning Sun, April 18, 1912

The Titanic



TITANIC TIMELINE

Sunday, April 14th 1912. North Atlantic Ocean, very calm sea, no moon

19:15 Other ships in the area inform Titanic about icebergs

22:00 Lookouts changed and told to "look out for ice"

22:50 "California" (20 miles N) tells wireless operator they have stopped and are surrounded by ice. Information not send to bridge due to other priorities.

23:40 Iceberg impact

00:00 Known that ship is lost, expected sinking in less than 2 hours

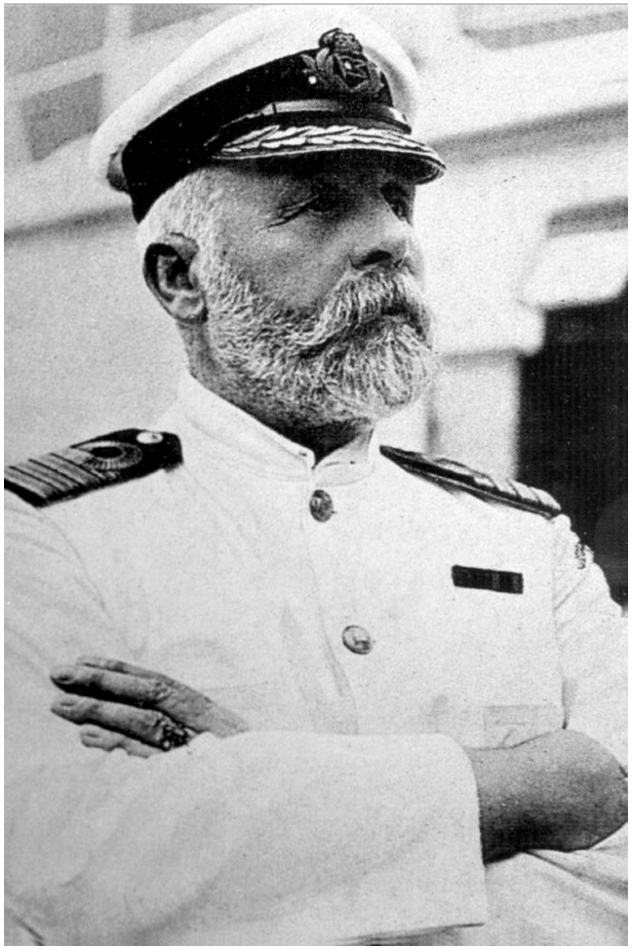
00:25 Order to abandon ship

00:45-02:05 18 lifeboats leave (average 60% full). Last two lifeboats swept away.

02:20 Ship sinks. 1500+ people still on-board die.

04:10 "Carpathia" arrives. 700 people rescued.

Operational mistakes in preparation…



How <u>not</u> to be a hero….

Could Captain Smith have prepared better before he left for America?

- Questioned the basic assumption on ship's safety
- Ran through some "what if" scenarios, even as thought exercises.
- Performed an abandon ship rehearsal for passengers and/or crew
- Organised full testing of the lifeboat system under realistic conditions
- Found out and fully understood the lifeboat system loading assumptions

He fell for the narrative and ludic fallacy….

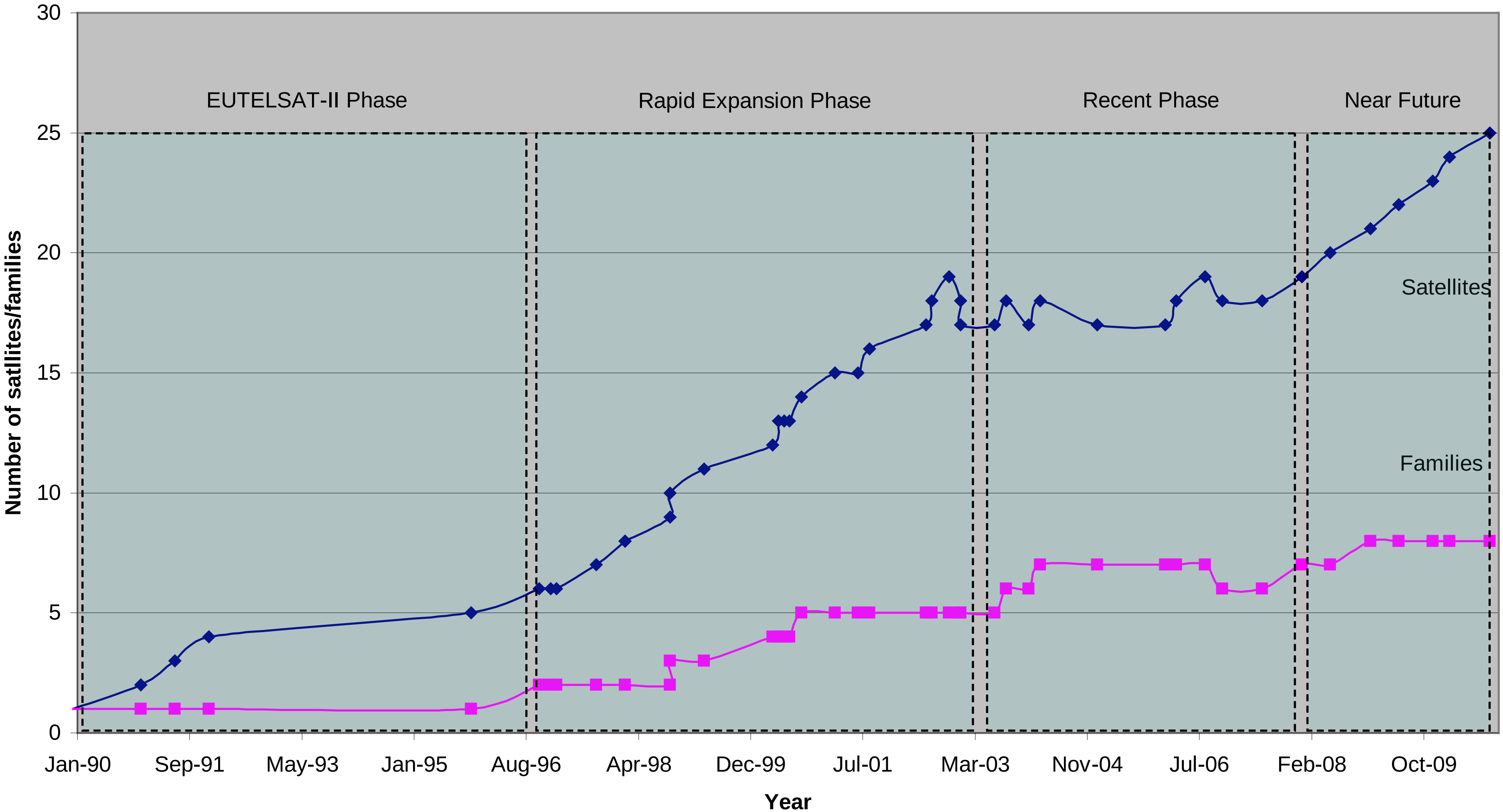
Operational mistakes on the day…

How not to be a hero….

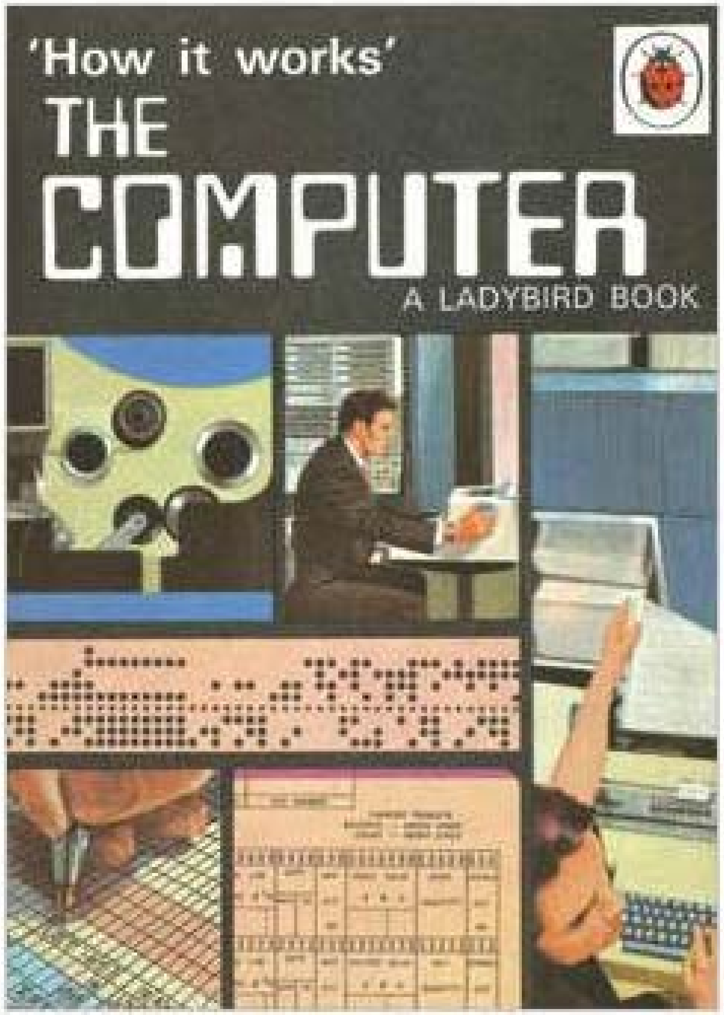
How could Captain Smith have played defensively when he heard that there was icebergs in the area?

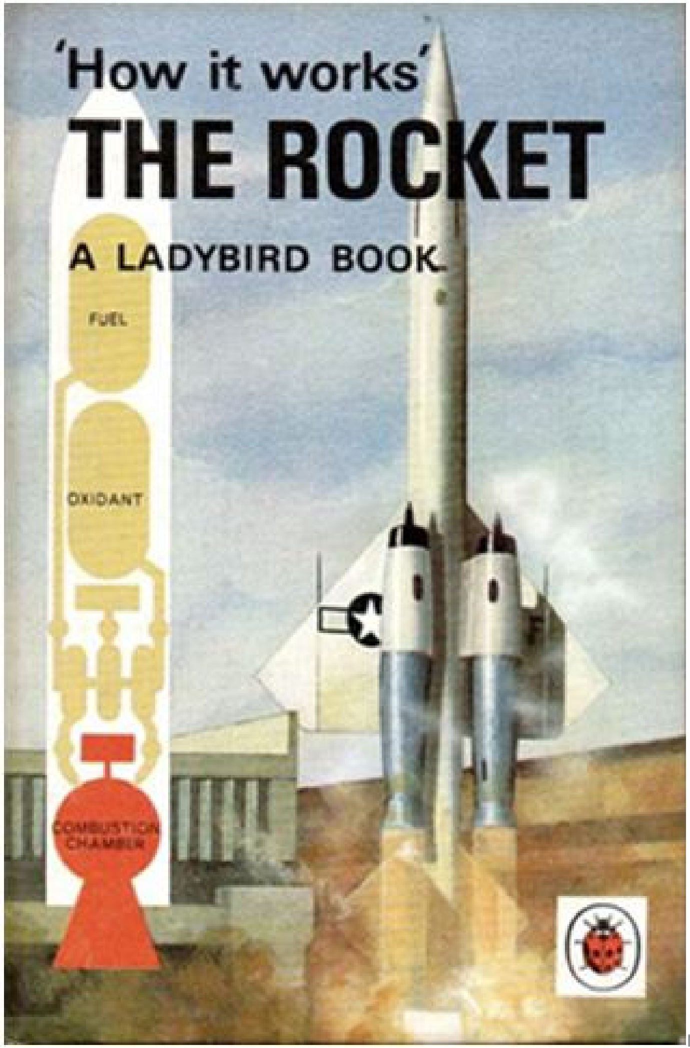
How could Captain Smith have played defensively once they hit the iceberg?

The Ladybird Guide Story

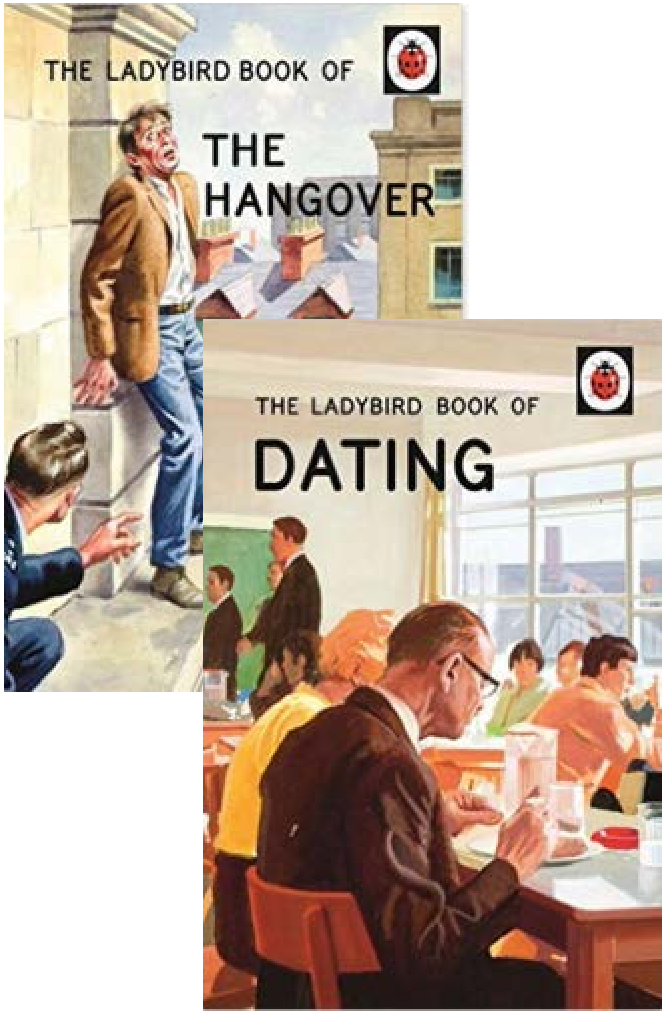


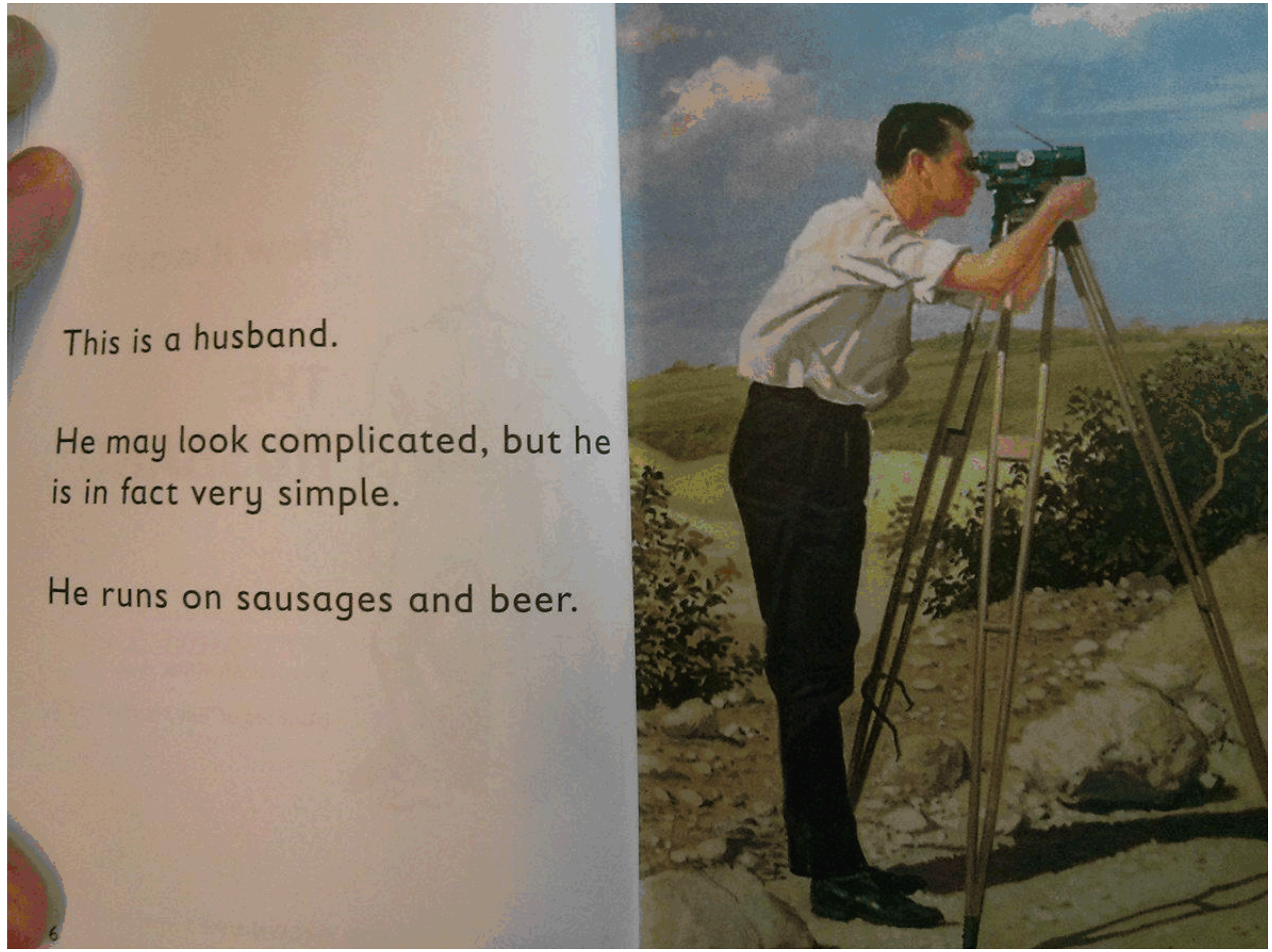
The Original Ladybird Guides





The New Ladybird Guides





My Ladybird Take on Spacecraft

There are different types of missions and spacecraft designs. It can seem confusing!

But remember:

- **Every mission has common problems to solve**
- **Each subsystem design is <u>one</u> solution to a <u>common</u> problem**

Try to understand the problems <u>before</u> the solutions

Each spacecraft manufacturer will try and differentiate himself from his competitors.
So it is no surprise that these commonalties are not explicit in user manuals.

It is up to you, the operator, to identify and understand the problems from first principles
The Ladybird Guide is a way to help you with this…….

Chapter 1

THE MISSION

The Mission

It is very important to understand what the satellite has been launched to do before diving into the technical documentation on how it does it.

This is called the mission goals

The mission goals will place requirements on the payload

In turn the payload will place requirements on its support systems

The Mission Goals

Mission goals are very varied.

Here is a typical example from an Earth Observation mission:

Take 20 pictures of the earth per day and transmit them to the ground within 24 hours of them being taken.

Each picture must have a quality Q, and cover S km^2 on the earth.

Requests for pictures must be able to dealt with up to X days before their execution on-board and delivered to the requester within Y days of them being taken.

The Mission Goals

The mission goals have profound implications for the spacecraft and ground design.

Take 20 pictures of the earth per day and transmit them to the ground within 24 hours of them being taken.

(On-board memory size, choice of ground stations, downlink rate etc)

Each picture must have a quality Q, and cover S km^2 on the earth.

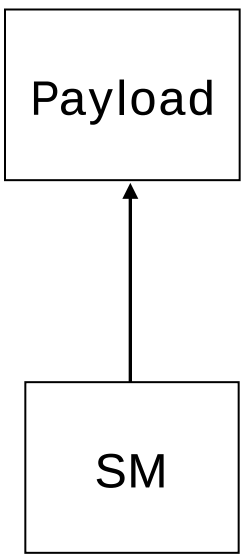
(Camera choice, orbit altitude, attitude stability, data compression etc)

Requests for pictures must be able to dealt with up to X days before their execution on-board and delivered to the requester within Y days of them being taken.

(Planning cycle, weekend working, ground automation and interfaces, on-board timetag queue size, ground network speeds, ground processing of images etc)

The two modules

To accomplish the mission the spacecraft is split into two modules:

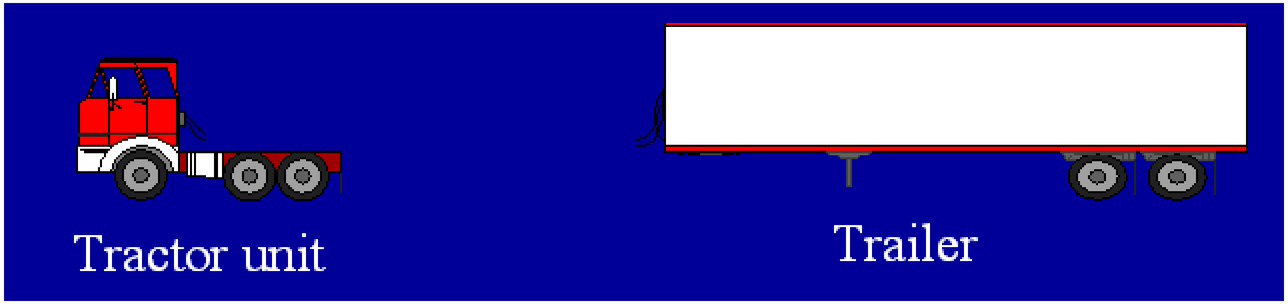


A payload which actually performs the mission

A service module (sometimes called the bus) which provides all the services required to support the payload in orbit

Trucks and Trailers

Splitting the spacecraft into these two modules is not a strange concept for us. Consider the way a truck is designed. It is also split into two parts.

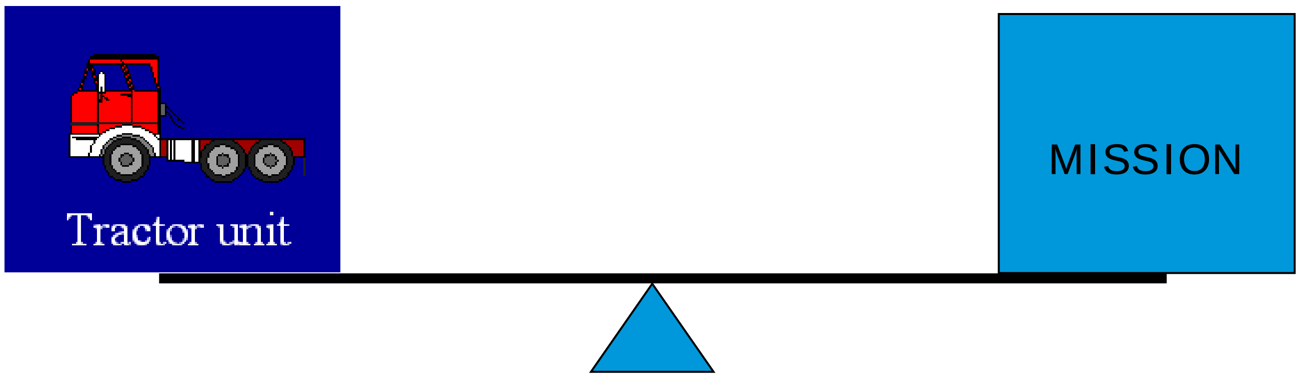


The tractor unit provides such things as guidance, motion & electrical power to the trailer, while the trailer actually carries the customer's goods.

As tractor units are designed to support different trailers, so spacecraft manufacturers try to design SMs that can support different payloads. They do this by making them as far as possible, payload independent.

The payload can be considered as a unit that plugs into the SM, just like the truck & trailer.

The big fight



Mission's always want something special, while the service module providers want to offer something standard.

Back to the mission goals

We will use the example of a typical telecoms satellite to illustrate the process.

QUIZ: What are the mission goals of a typical geo-stationary telecom mission?

RECEIVE the customer's RF channels

AMPLIFY them &

RETRANSMIT them back at the earth

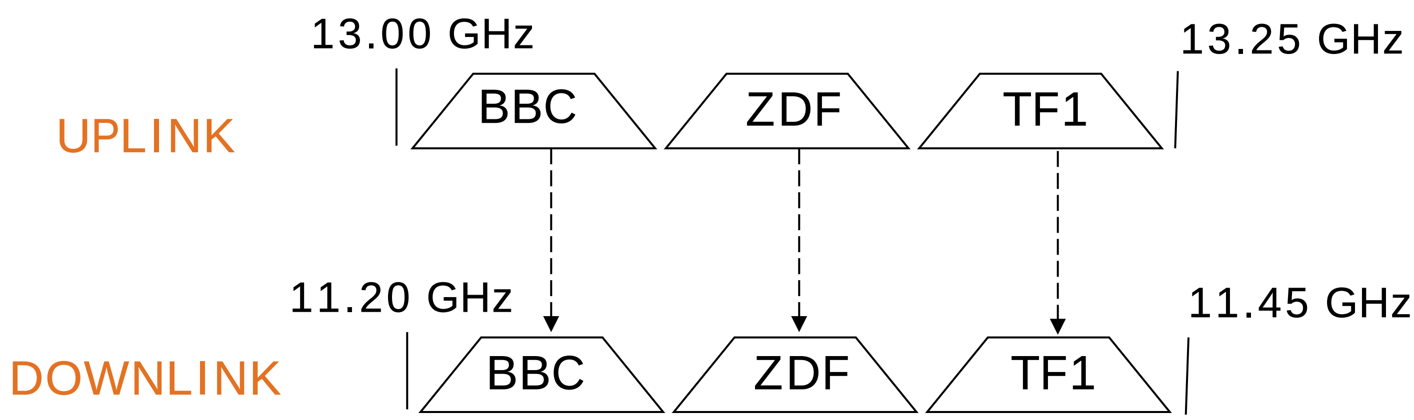
Channels

A channel is a small frequency band that is allocated to the customer.

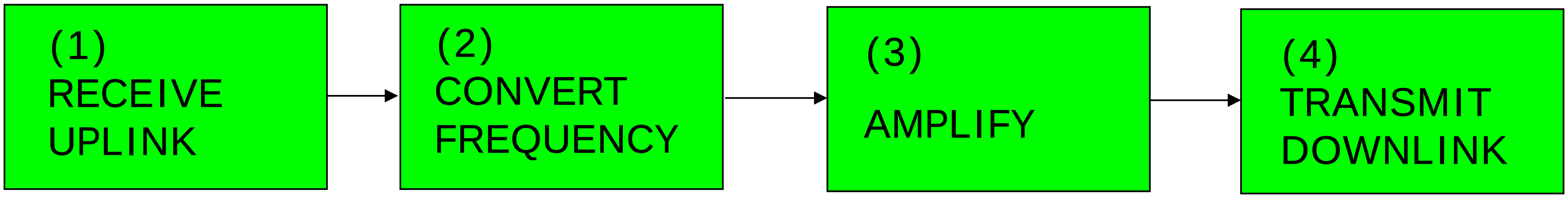
The operator is allocated larger bands for transmitting to UPLINK and from DOWNLINK the satellite by an international body (ITU).

The operator splits up these large bands up into smaller *channels* and sells them as part of a communication service.

To avoid interference between the uplink and downlink must use different frequencies. Hence the payload must convert from the uplink to the downlink frequency in orbit.



Mission Summary



(1) Receive the uplink from the earth which are made up of channels,

(2) Convert from the uplink to the downlink frequencies,

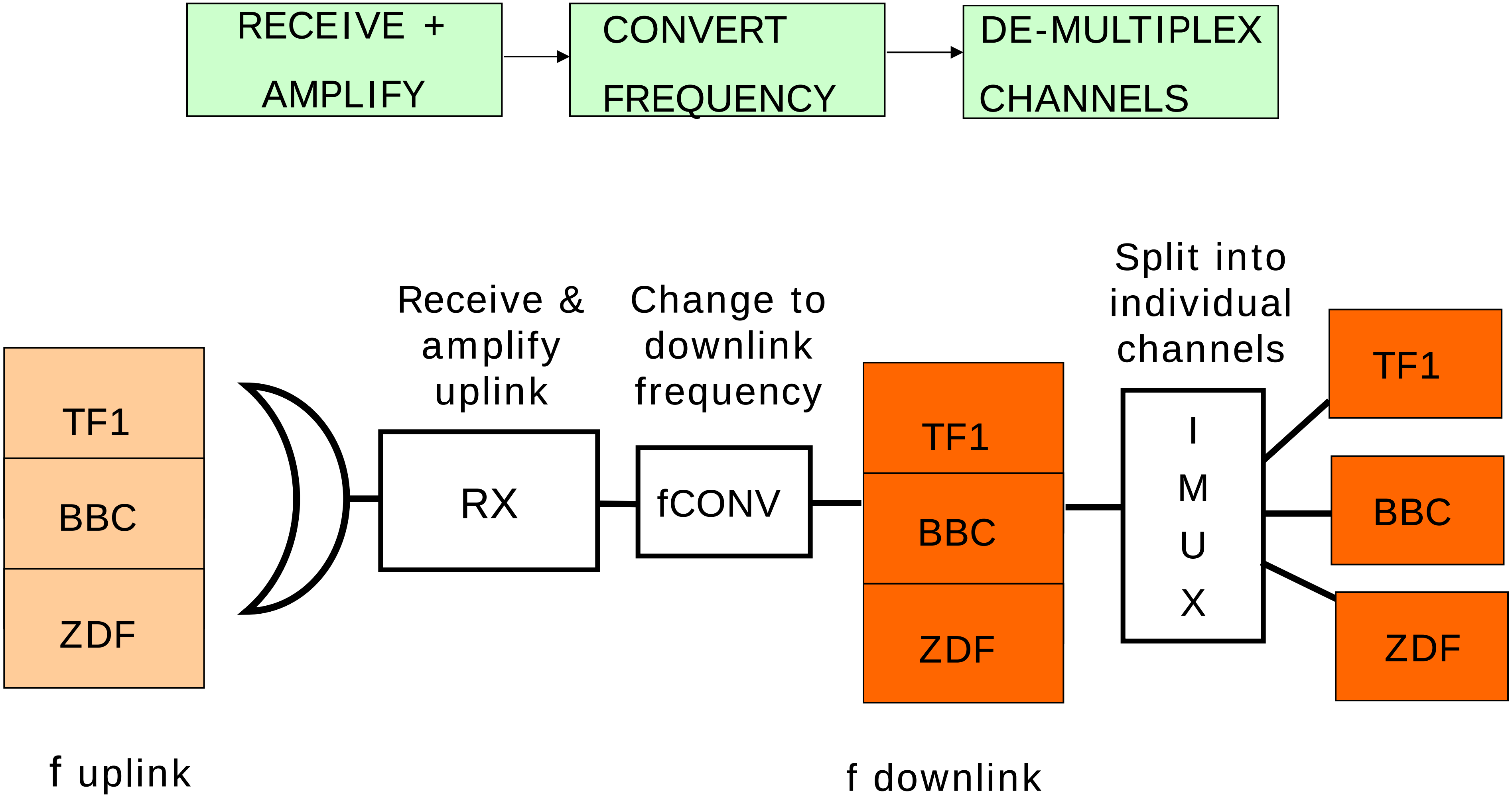
(3) Amplify all the channels,

(4) Transmit the downlink back to the earth

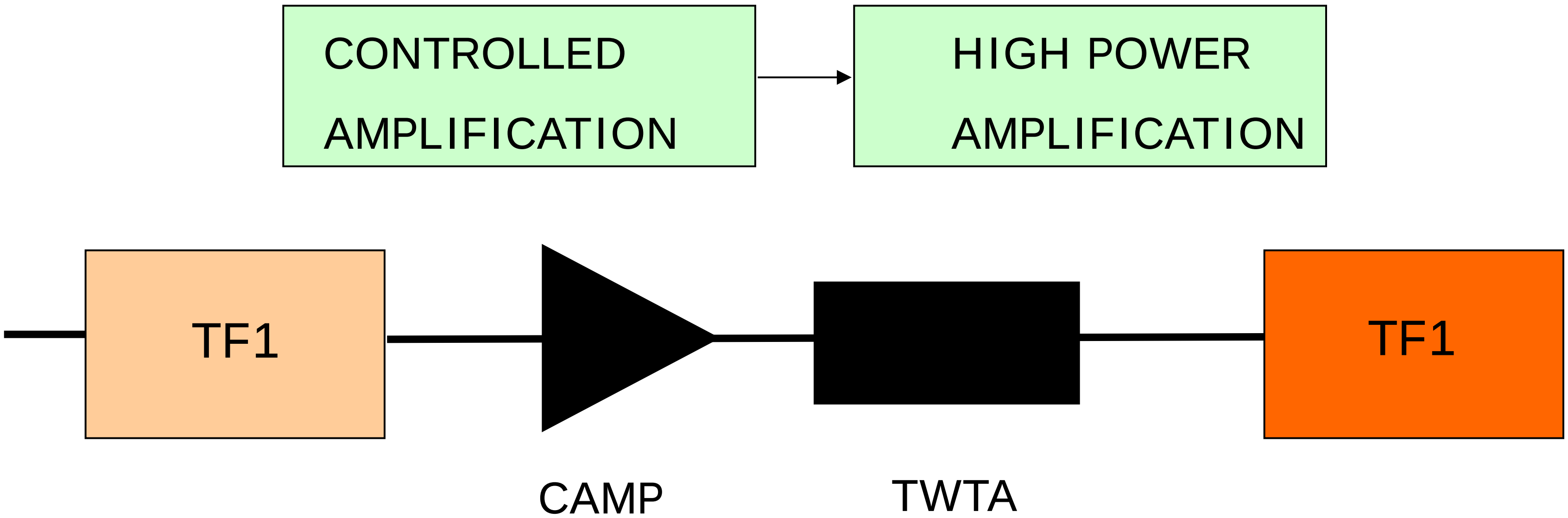
Chapter 2

THE PAYLOAD

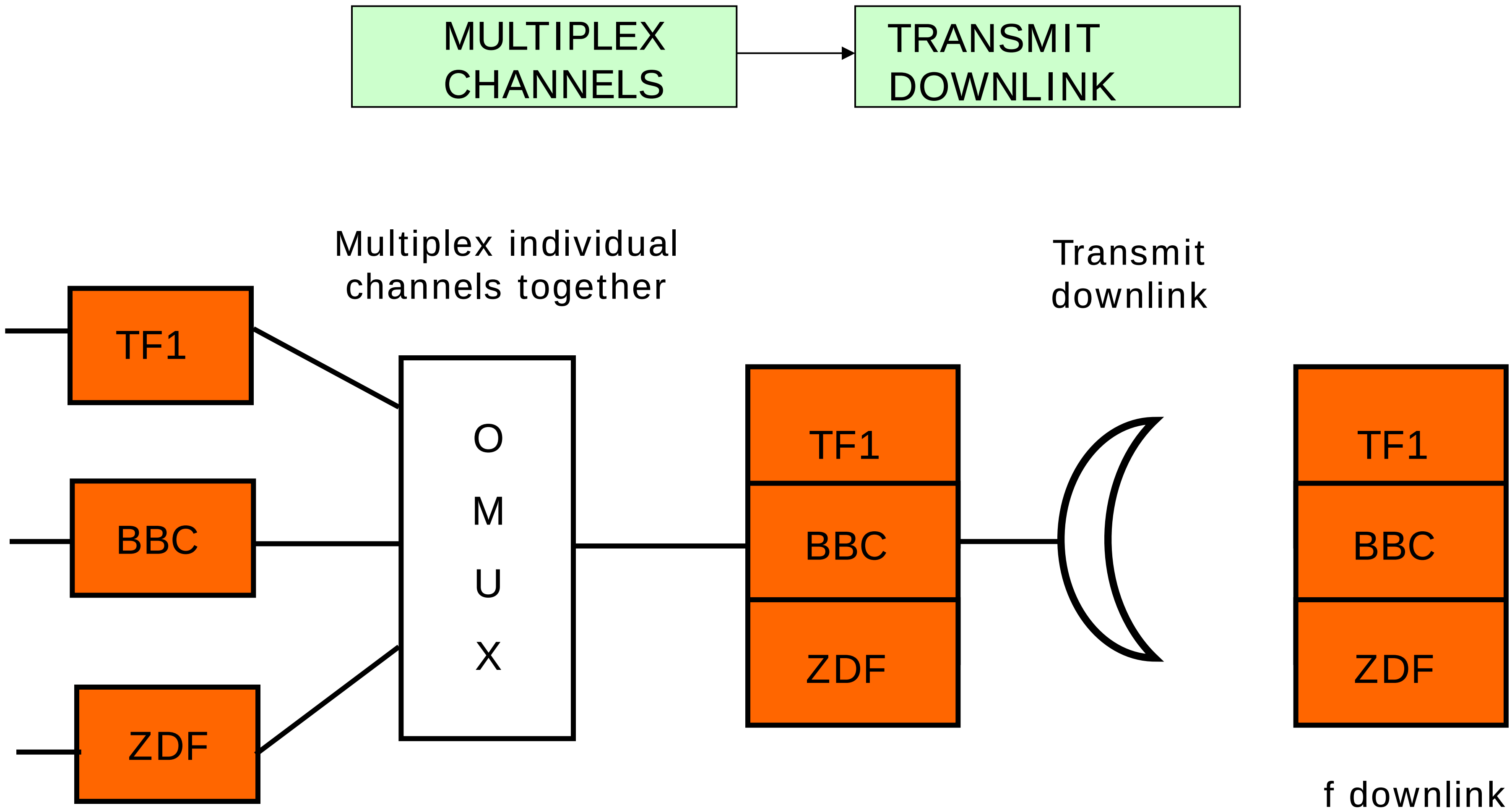
Receive Chain



Amplification chain

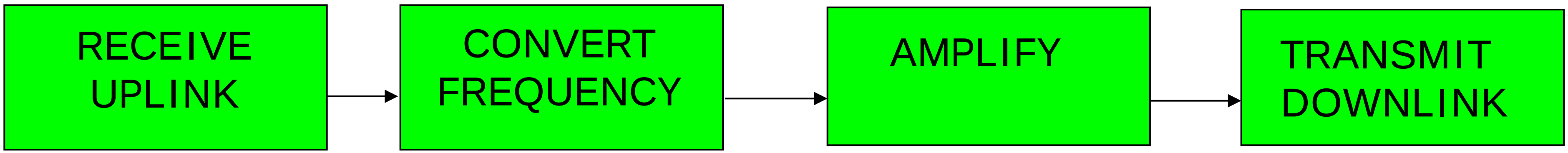


Transmit chain diagram

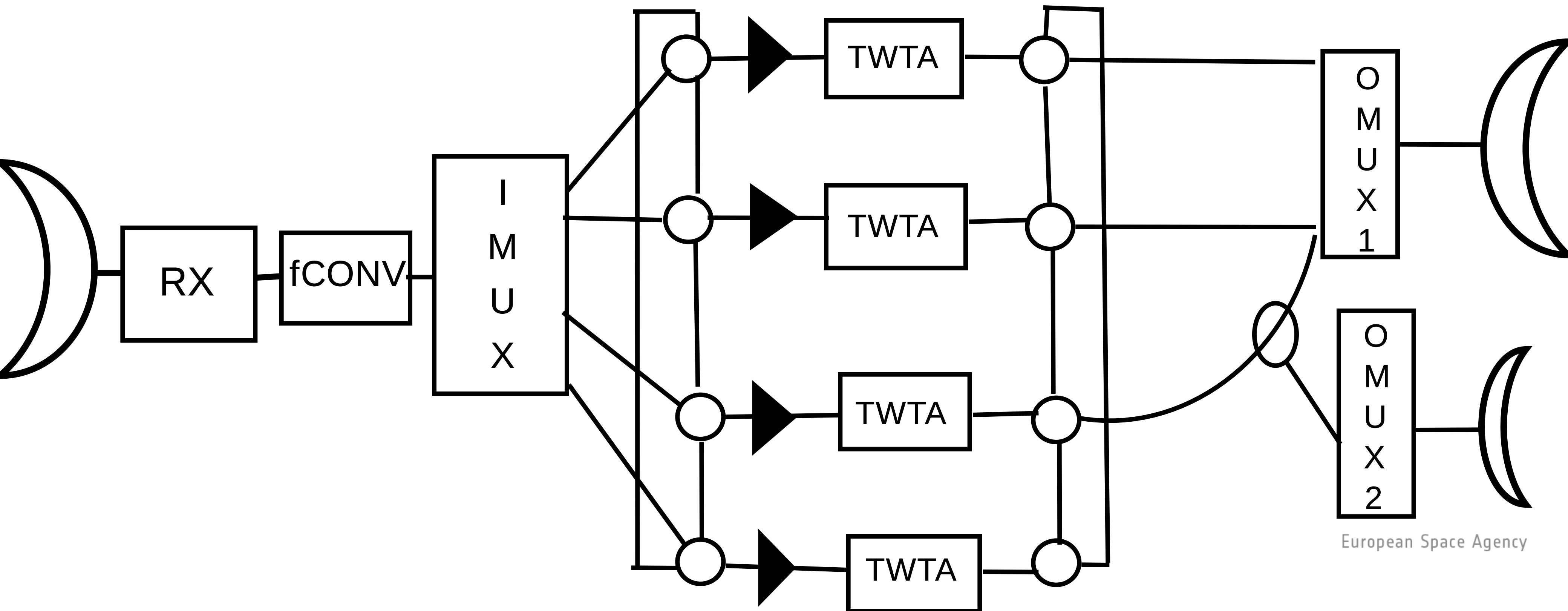


Basic system diagram

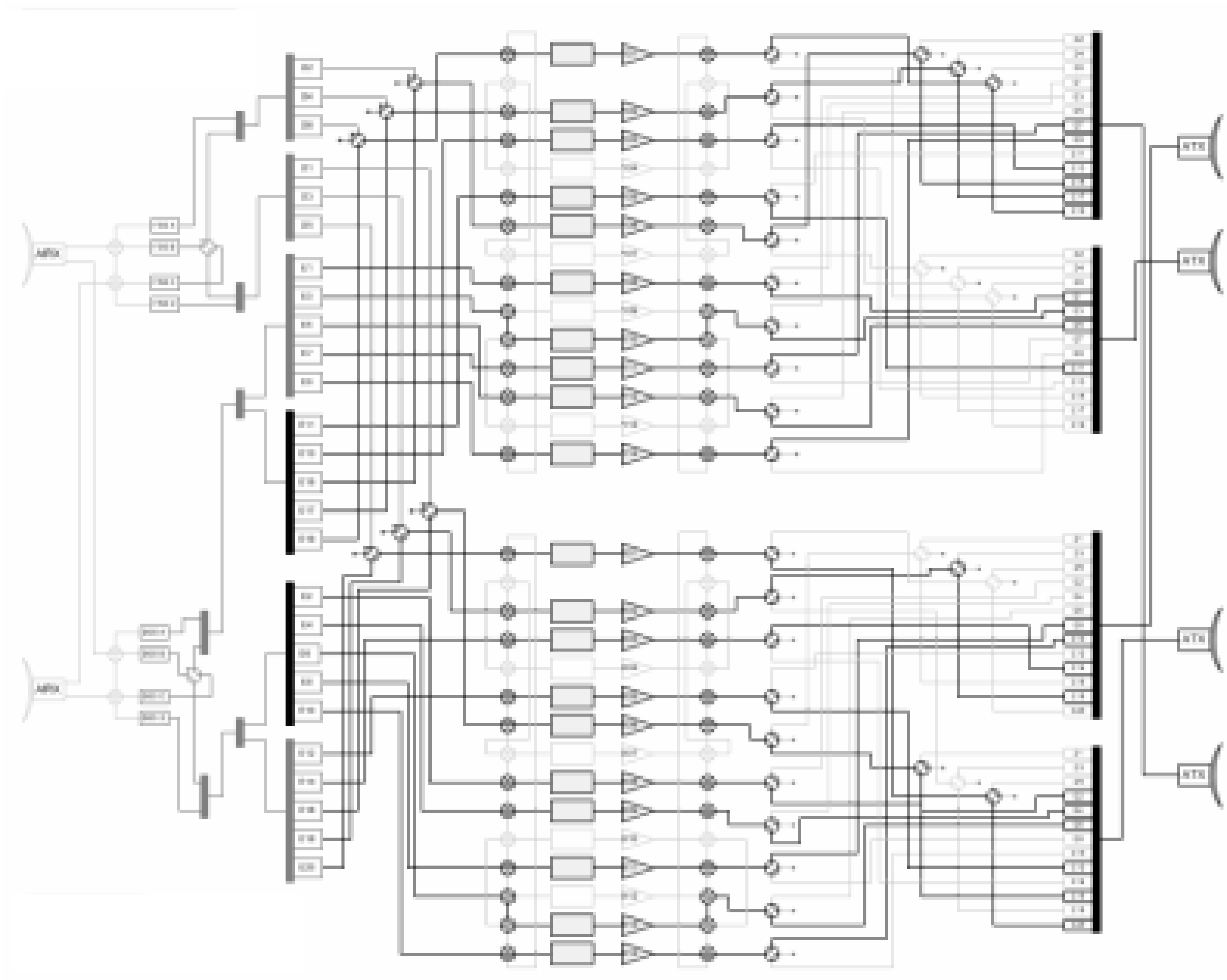
FUNCTIONS



SUBSYSTEM

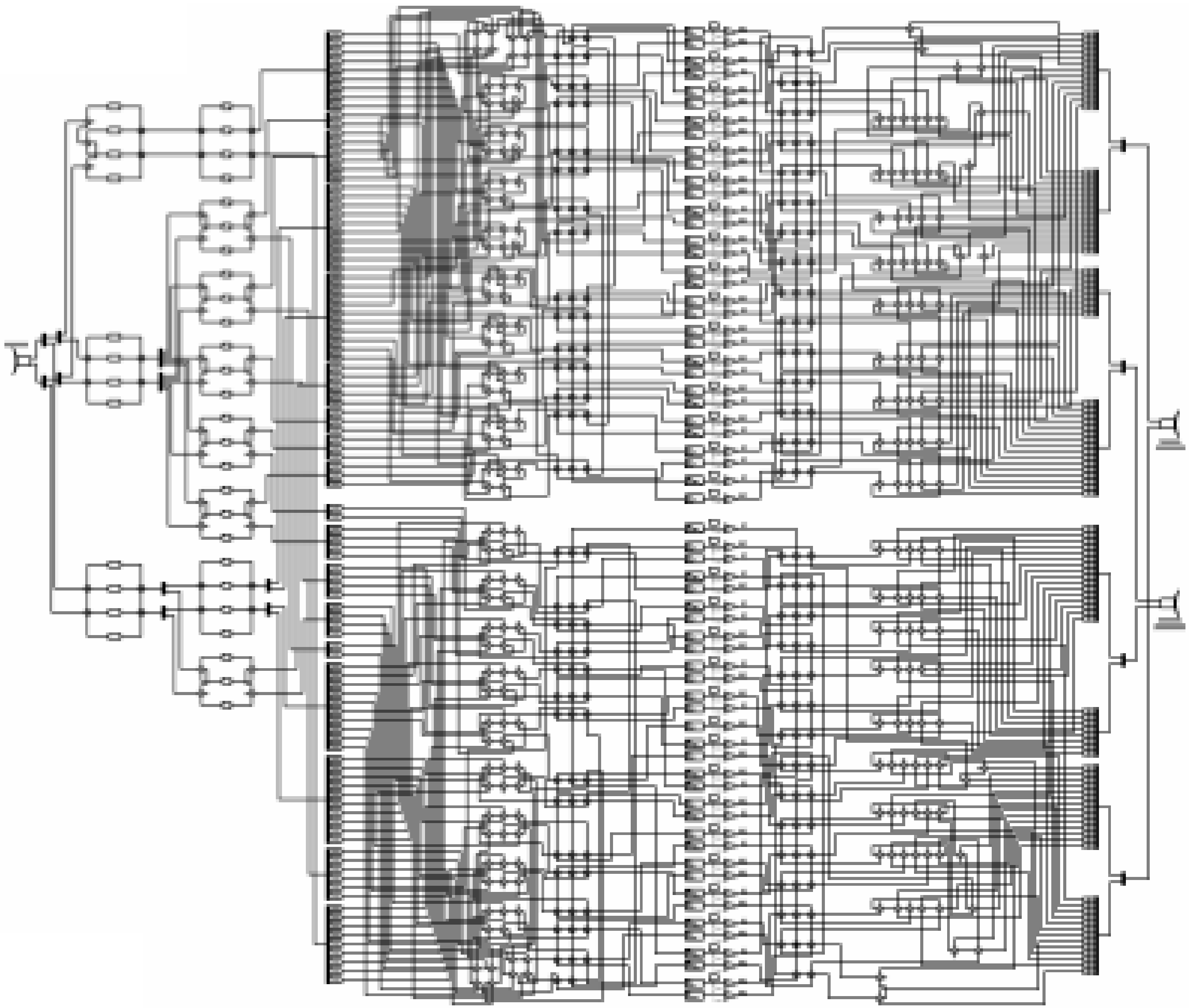


From a simple concept to reality



1997

and it never gets simpler…



2007

1524 connections

400 switches

810 units

Operational Experience: Payload Operations

This is Herschel: The ice cold giant eye (May 09, L2, A5)

Biggest mirror (3.5 m diameter) flown in space, operated at 0.3K

Years before ground segment development starts instrument developers enquire how much data they can uplink?

ESOC answer: The uplink rate is 4 kbps and the instruments can use two from three hours of the daily contact window for uplinking data.

Later unveil instruments requiring a daily uplink of over 39000 TCs to be stored on-board! Too late to change the instruments.

But the mission control system could not handle this much command processing. 6 hours to import database, 6 minutes to load the commands on the system and 3 hours to uplink….

MCS had to be ported from sun workstations to Linux/PCs to gain speed.

QUIZ: What can we learn from this story?

Operational Experience: Lessons

- Instrument developers usually know little about operations. Don't expect them to guess operational constraints – be proactive
- Instrument design starts much earlier in a project than operations. You will be stuck with whatever they hand you - be proactive
- Information on the instrument operations (e.g. user manuals) are often delivered late and incomplete. Don't assume it will be any different on your mission – be proactive

Payloads ***are*** the mission. They are too important to be left on their own.

A story about a bonus scheme.

Sometimes instruments are more expensive than the bus and instrument operations are often far better funded than our own. (PROBA-V payload ground segment was allocated 7 times the budget of the control segment)

Chapter 3

THE SERVICE MODULE

The service module

The service module supports the Payload in orbit. It provides three main services:

ATTITUDE & ORBIT CONTROL	Needed to point the payload (or solar arrays) and move the spacecraft to correct orbit
POWER & THERMAL	Needed to power the payload and keep it warm/cold
COMMAND & TELEMETRY	Needed to allow the ground to monitor and control the payload

Each service shall be dealt with in turn. Let's look at attitude control.

esa academy

esa