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Structured innovation

Location, 01.11.2018

Apollo 13 – “Failure is not an option !”
A universal TRIZ Case Study

Agenda

12:45	Overall Introduction and Expectations
13:15	Intro to the Apollo 13 Case & Simulation
13:45	Simulation
15:15	Feedback
15:30	End

Get your role assigned

CMP Command module pilot:	Pilot in the capsule and commander of the mission
CapeCom	capsule communicator: interface between astronauts and Mission control
LMP	Lunar module pilot: Pilot of the lunar landing module.
LME	Lunar module engineer responsible for electrical, environmental, communications, structural and EVA (extra vehicular) systems.
Mission Crew	the three astronauts
Mission control center	Team at the Kennedy Space center
Flight director	Lead of Mission control and responsible for the mission
Support Engineers	
Methods support	the trainer team

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Introduction to the Apollo 13 Case

The Outline

The Apollo program, also known as Project Apollo, was the third United States human spaceflight program carried out by the National Aeronautics and Space Administration (NASA), which accomplished landing the first humans on the Moon from 1969 to 1972. First conceived during Dwight D. Eisenhower's administration as a three-man spacecraft to follow the one-man Project Mercury which put the first Americans in space, Apollo was later dedicated to President John F. Kennedy's national goal of "landing a man on the Moon and returning him safely to the Earth" by the end of the 1960s, which he proposed in an address to Congress on May 25, 1961. [1]

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Roles and responsibilities

Role(s)	Main task	Role during simulation	Number
CMP Command module pilot.	Pilot in the capsule and commander of the mission		1
CapeCom	Capsule communicator: interface between astronauts and Mission control	Interface between mission control and mission crew. Deliveres instruction to the mission crew.	1
LMP	Lunar module pilot: Pilot of the lunar landing module.	Has specific knowledge about the LM. (Get extra info)	1
LME	Lunar module engineer responsible for electrical, environmental, communications, structural and EVA (extra vehicular) systems.	Part of the mission control center however a specific role.	1
Mission Crew	Mission Crewi	Get advices from mission control an build solution according the plans delivered	3 (2+LMP)
Mission control center	Lead of Mission control and responsible for the mission	Organise all the team members	All the other participants – main team for problem solving
Methods support	Deliver short training on TRIZ	Guidance for tool application	2

Launching the Apollo 13 Mission
TRIZ Simulation

Launching of Apollo spaceship - video

Orignal launch video

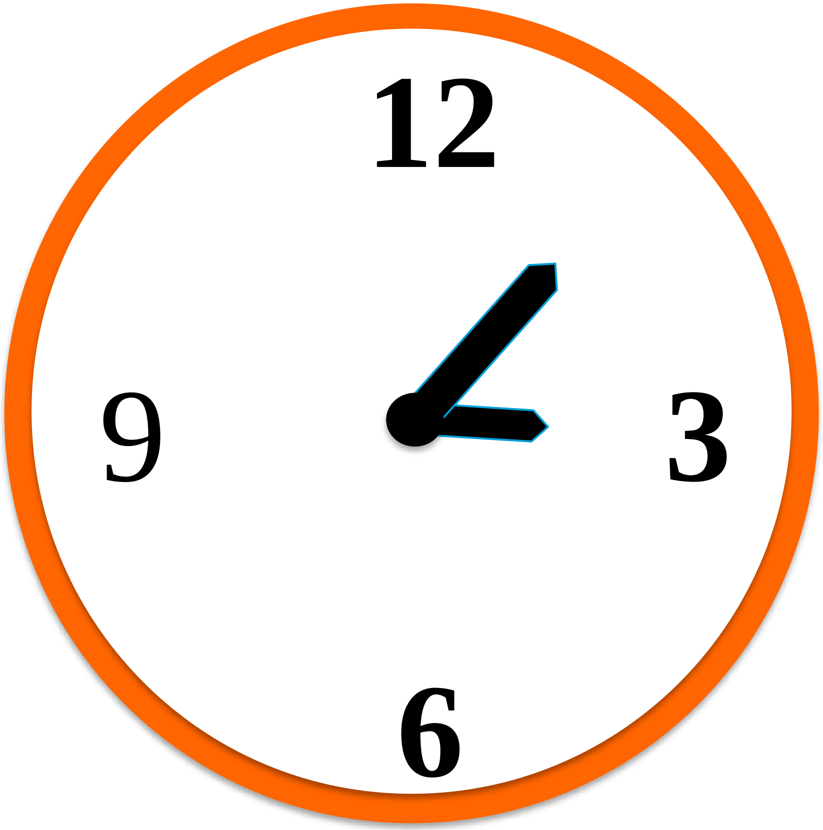
The Accident – not yet clear what happened

April 14, 1970 UTC (April 13, 21:07:53 CST)

Houston, we have a problem: 03:07:53 UTC (55:54:53 Ground Elapsed Time);[6] 173,790.5 nmi (321,860 km) from Earth[7]

Here we show the sequence of the communication between the capsule and mission control. “**Houston, we have a problem” video sequence.**

The Accident



The astronauts communicated " Houston, we have had a problem

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Some hints

- We have defined roles and a tasks for the role
- Most of us are the part of mission control
- We have a few expert on TRIZ in the mission control
- The flight director controls and guides the team
- The methods team explains each tool we will use it immediately by applying the learned generating solutions
- Solution concept cards are documenting our solutions
- Performance indicators are ideas to solve the problems in the spaceship
- Solutions are validated by the „Validator“ to be build by the crew.

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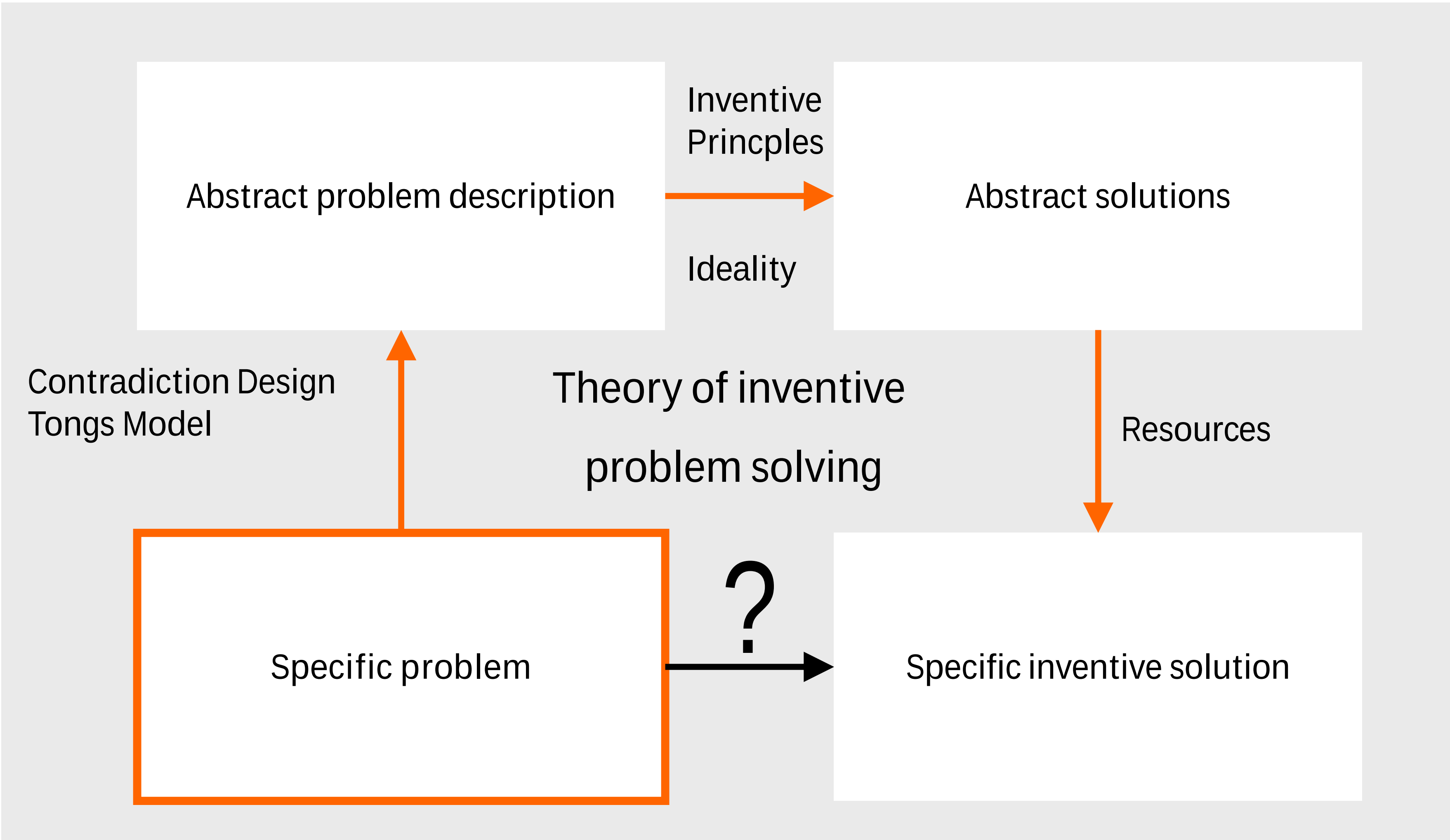
Methodolgy to save the astronauts

TRIZ as a Process



Set of Tools for Problem Solving

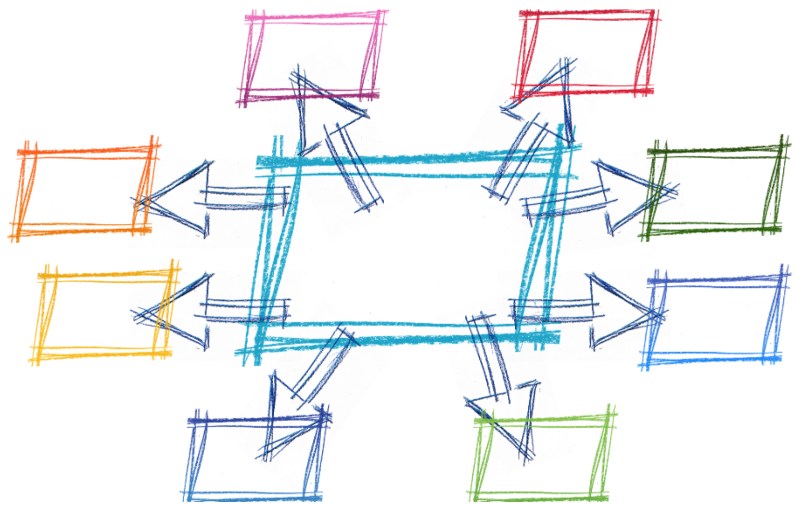
TOM's
Model
-
Strive for ideality

Resource
Topology
-
Using what
exists right there

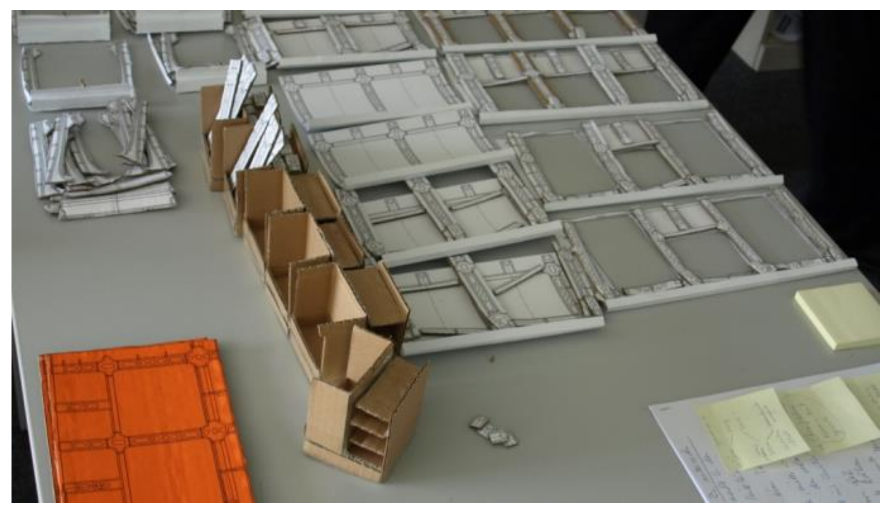
Contradiction
Matrix
-
Avoid
compromises

Challenge: Apollo 13
OTSM - TRIZ and Fast prototyping

OTSM - Network of Problems and Solutions
-
Knowledge Base complexity mapping



Prototyping
-
Fast learning



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Facilities for your usage

Simulation Boards

Contradiction Board

Solution Concept Board

Resource Board

KPI Board

Solution Concept Cards

Solution concept description/sketch

Estimated impact

Resources needed

Time for realisation

Validated concept:

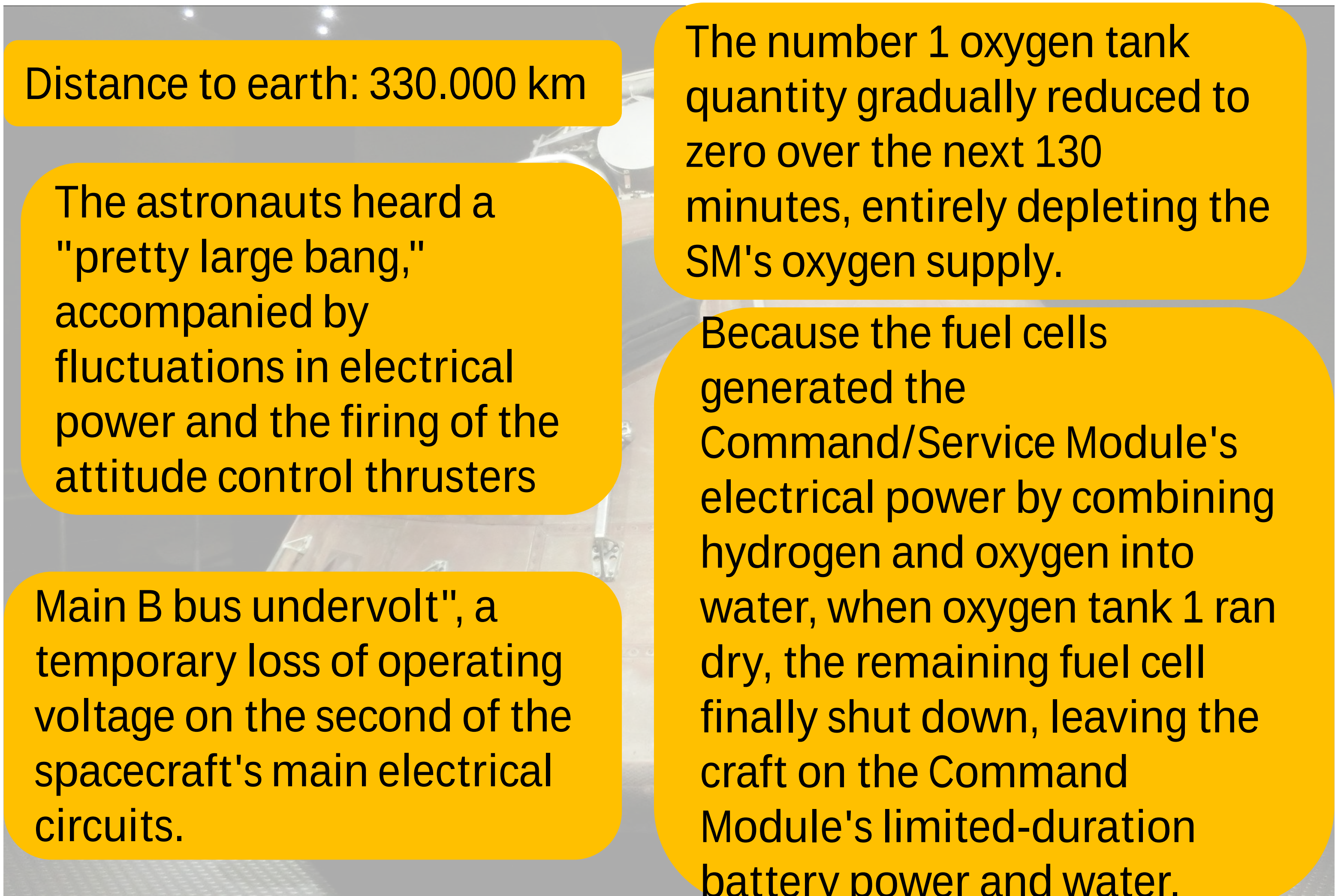
Yes:

No:

Signature:

Think Ideal

Initial Situation



Distance to earth: 330.000 km

The astronauts heard a "pretty large bang," accompanied by fluctuations in electrical power and the firing of the attitude control thrusters

Main B bus undervolt", a temporary loss of operating voltage on the second of the spacecraft's main electrical circuits.

The number 1 oxygen tank quantity gradually reduced to zero over the next 130 minutes, entirely depleting the SM's oxygen supply.

Because the fuel cells generated the Command/Service Module's electrical power by combining hydrogen and oxygen into water, when oxygen tank 1 ran dry, the remaining fuel cell finally shut down, leaving the craft on the Command Module's limited-duration battery power and water.

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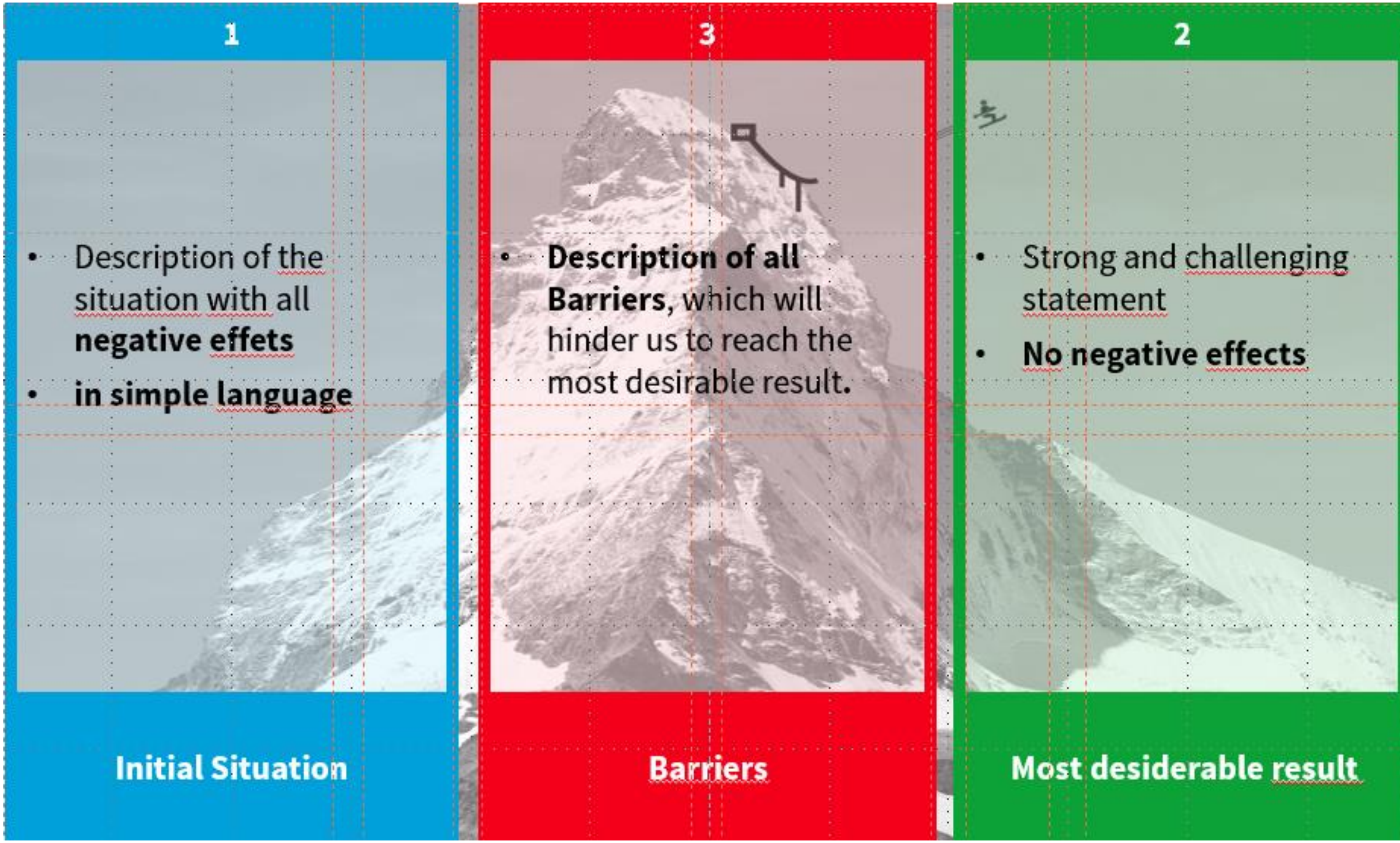
TOM's Modell
Template



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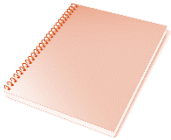
TOM's Modell
Exercise



Vorgehen

Describe the TOM's Model

- Describe the initial situation
- Define the ideal final result and an achieveable „most desireable result“
- List all barriers you know

Result

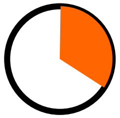
- A preicuse overview of the problem situation and problems we have to solve

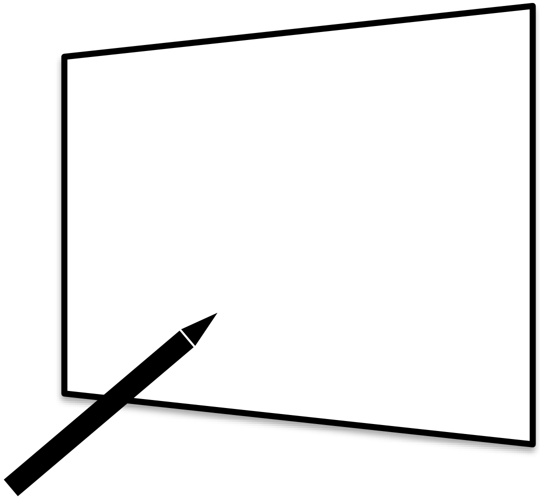
Material

- Template TOM's Modell
- Initial situation description

Time:

- 20 minutes





Using Existing Resources

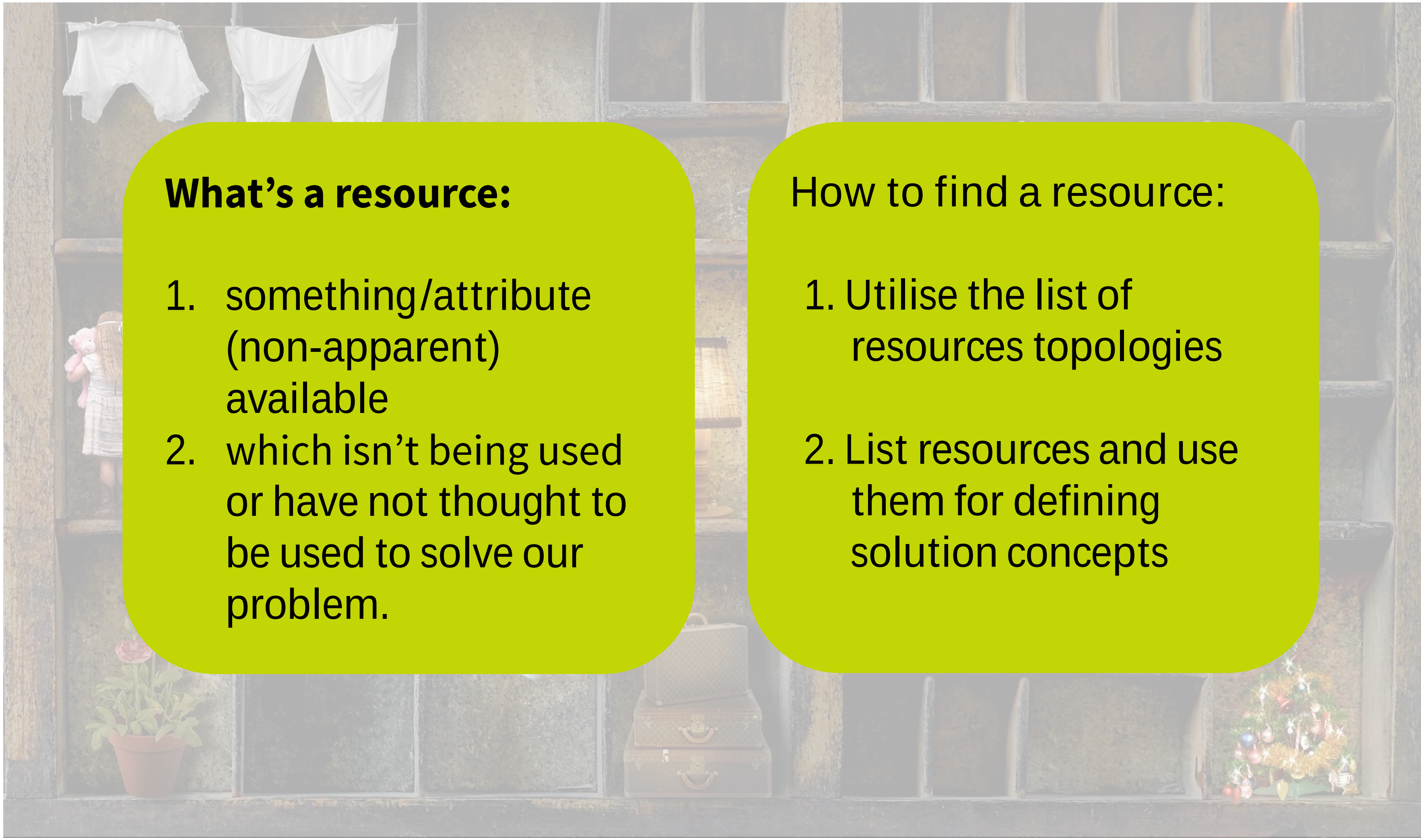
Increasing carbon dioxide in the air

The Lunar Module was designed for only two people for a 36-hour period, not three astronauts for 96 hours. They quickly discovered that carbon dioxide was building up fast, putting their lives in extreme danger. They had to change the circular CO2 scrubbers in the Lunar Module for clean ones, but they only had spare square CO2 scrubbers from the Command Module.

Video sequence with filters

Source: https://sploid.gizmodo.com/this-is-the-actual-hack-that-saved-the-astronauts-of-th-1598385593

Concept of using existing resources



What's a resource:

1. something/attribute (non-apparent) available
2. which isn't being used or have not thought to be used to solve our problem.

How to find a resource:

1. Utilise the list of resources topologies
2. List resources and use them for defining solution concepts

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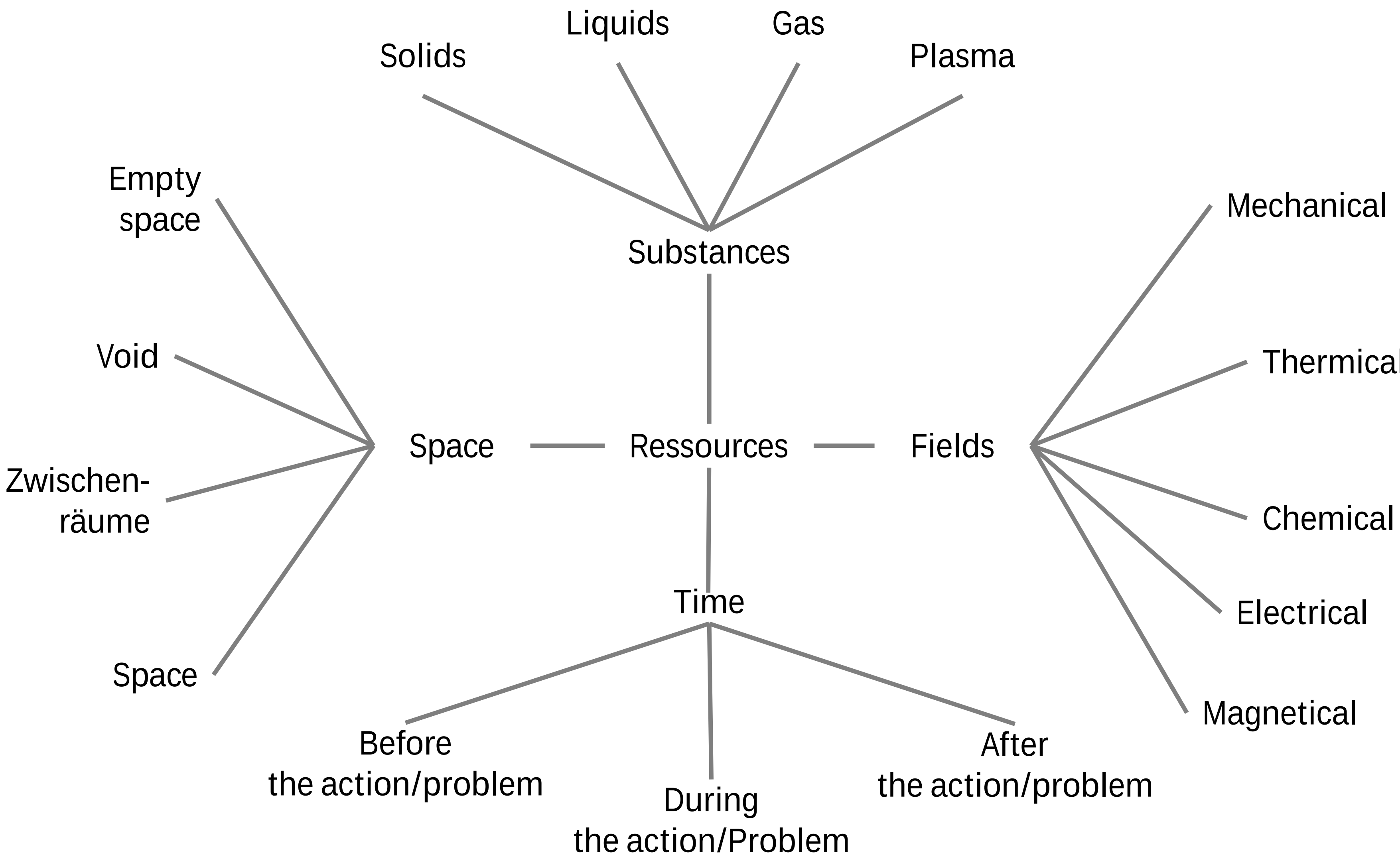
Challenge: Apollo 13
Template –Resources



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Apollo resources

2 lithium-hydroxide canisters

Roll of gray duct tape

2 LCG bags

2 hoses from the red suits

2 socks

1 bungee cord (to secure the modified filtration device to the wall of the LM)

Food

Bags

Clothes

Books

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Challenge: Apollo
Ressourcen

Goals

- Check all resources in reachable environment
- Create an overview of existing resources
- Think about how the resources could be used to solve your problem

Results:

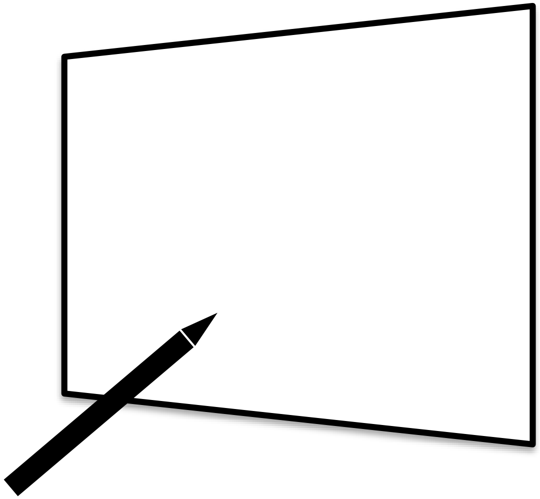
- List of ressources
- Ideas to solve your problem

Material

- Template
- Apollo ressource board

Time:

- 15 minutes



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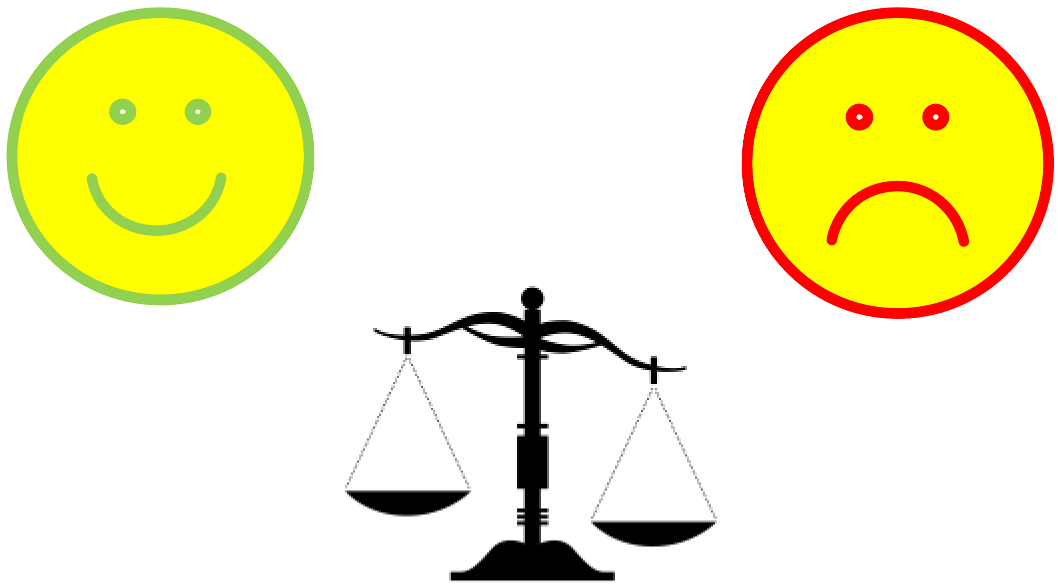
Thinking in Contradictions

Technical Contradiction

If something is improved, something else is getting worse.



Modeling a Problem as a Contradiction makes is possible to reuse the knowledge of others who already solved the problem

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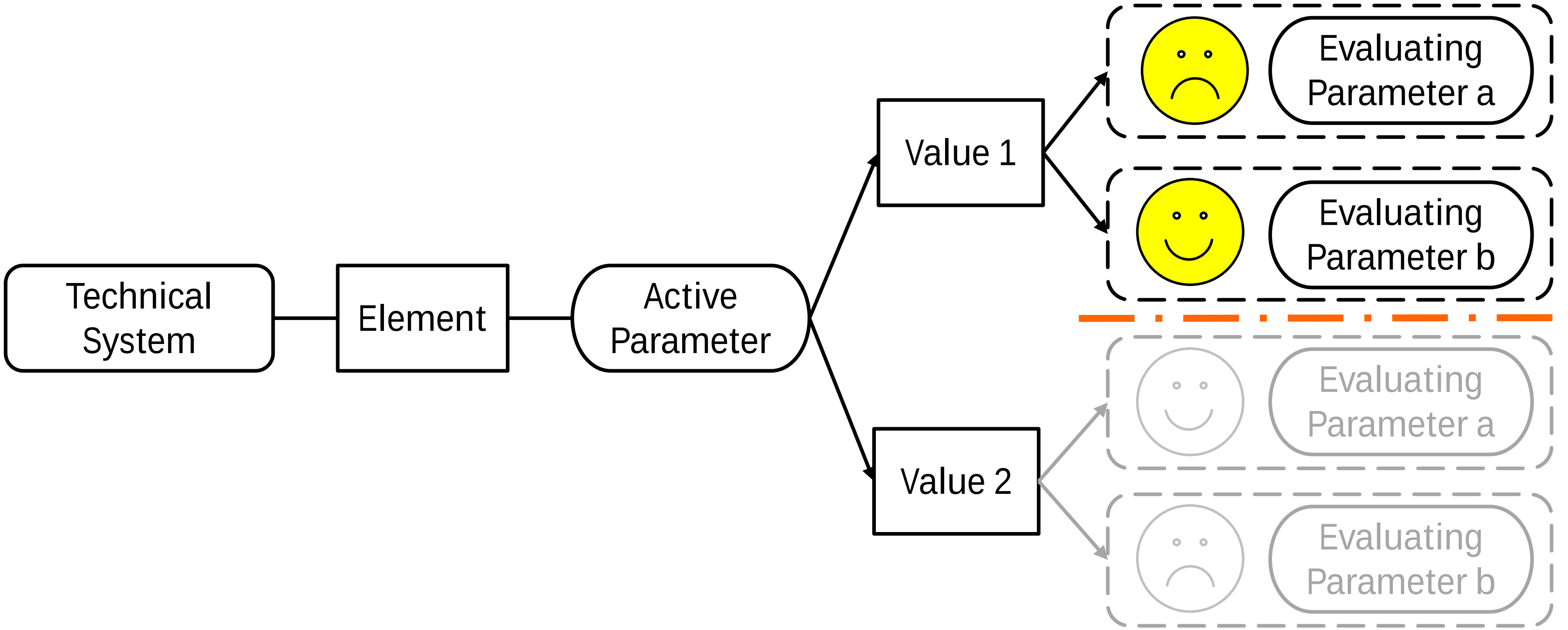
Element-Name Value Contradiction Model

Template



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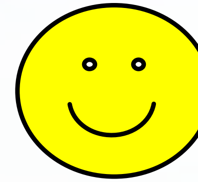
Some Apollo key conflicts - generic

energy use reduction	
temperature	

cooling of equipment	
essource	

# use of rocket engines for control	
Damages	

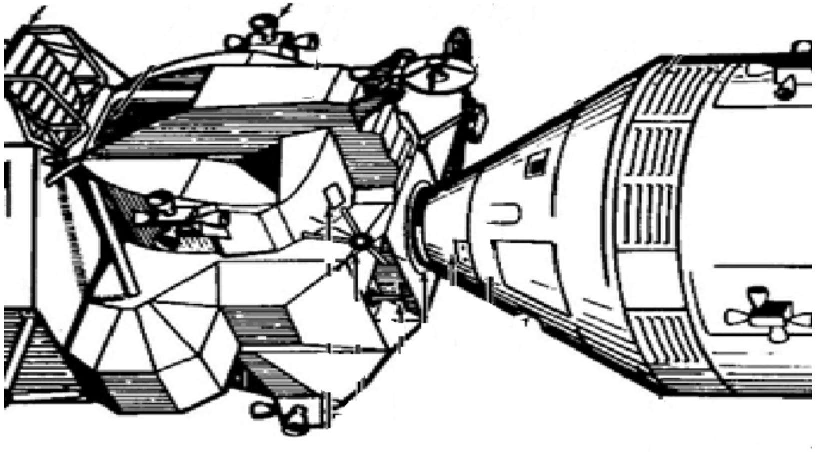
Pressure	
Damages	

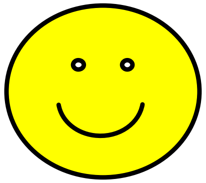
Apollo‘s last problem to solve

The last problem to be solved was how to separate the Lunar Module a safe distance away from the Command Module just before re-entry. The normal procedure was to use the Service Module's reaction control system (RCS) to pull the CSM away after releasing the LM along with the Command Module's docking ring, but this RCS was inoperative because of the power failure, and the useless SM would be released before the LM. To solve the problem, Grumman called on the engineering expertise of the University of Toronto. A team of six UT engineers, led by senior scientist Bernard Etkin, was formed to solve the problem within a day. The team concluded that pressurizing the tunnel connecting the Lunar Module to the Command Module just before separation would provide the force necessary to push the two modules a safe distance away from each other just prior to re-entry.

A too high a pressure might damage the hatch and its seal, causing the astronauts to burn up; too low a pressure would not provide enough separation distance of the LM.

One key Apollo conflict – using TRIZ parameter



Force	
Damage	

Tools to be used to solve Conflicts

1. List of standard TRIZ parameter

1	Weight of moving object
2	Weight of stationary object
3	Length of moving object
4	Length of stationary object
5	Area of moving object
6	Area of stationary object
7	Volume of moving object
8	Volume of stationary object
9	Speed
10	Force (Intensity)
11	Stress or pressure
12	Shape
13	Stability of the object's composition
14	Strength
15	Duration of action of moving object
16	Duration of action of stationary object
17	Temperature
18	Illumination intensity
19	Use of energy by moving object
20	Use of energy by stationary object
21	Power
22	Loss of Energy
23	Loss of Substance
24	Loss of Information
25	Loss of Time
26	Quantity of substance
27	Reliability
28	Measurement accuracy
29	Manufacturing precision
30	Object-affected harmful factors
31	Object-generated harmful factors
32	Ease of manufacture
33	Ease of operation
34	Ease of repair
35	Adaptability or versatility
36	Device complexity
37	Difficulty of detecting and measuring
38	Extent of automation
39	Productivity

2. Contradiction matrix

	Worsening Feature → / Improving Feature ↓	Weight of moving object	Weight of stationary object	Length of moving object	Length of stationary object	Area of moving object	Area of stationary object	Volume of moving object	Volume of stationary object	Speed	Force (Intensity)	Stress or pressure	Shape	Stability of the object's composition	Strength	Duration of action of moving object	Duration of action of stationary object	Temperature
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Weight of moving object	+	-	15, 8, 29,34	-	29, 17, 38, 34	-	29, 2, 40, 28	-	2, 8, 15, 38	8, 10, 18, 37	10, 36, 37, 40	10, 14, 35, 40	1, 35, 19, 39	28, 27, 18, 40	5, 34, 31, 35	-	6, 29, 4, 38
2	Weight of stationary object	-	+	-	10, 1, 29, 35	-	35, 30, 13, 2	-	5, 35, 14, 2	-	8, 10, 19, 35	13, 29, 10, 18	13, 10, 29, 14	26, 39, 1, 40	28, 2, 10, 27	-	2, 27, 19, 6	28, 19, 32, 22
3	Length of moving object	8, 15, 29, 34	-	+	-	15, 17, 4	-	7, 17, 4, 35	-	13, 4, 8	17, 10, 4	1, 8, 35	1, 8, 10, 29	1, 8, 15, 34	8, 35, 29, 34	19	-	10, 15, 19
4	Length of stationary object		35, 28, 40, 29	-	+	-	17, 7, 10, 40	-	35, 8, 2,14	-	28, 10	1, 14, 35	13, 14, 15, 7	39, 37, 35	15, 14, 28, 26	-	1, 10, 35	3, 35, 38, 18
5	Area of moving object	2, 17, 29, 4	-	14, 15,	-	+	-	7, 14, 17, 4		29, 30, 4,	19, 30,	10, 15,	5, 34, 29, 4	11, 2, 13, 39	3, 15, 40, 14	6, 3	-	2, 15, 16
6	Area of stationary object	-	30, 2, 14, 18	-	26, 7, 9, 39	-	+	-		-	1, 18, 35, 36	10, 15, 36, 37		2, 38	40	-	2, 10, 19, 30	35, 39, 38
7	Volume of moving object	2, 26, 29, 40	-	1, 7, 4, 35	-	1, 7, 4, 17	-	+	-	29, 4, 38, 34	15, 35, 36, 37	6, 35, 36, 37	1, 15, 29, 4	28, 10, 1, 39	9, 14, 15, 7	6, 35, 4	-	34, 39, 10, 18
8	Volume of stationary object	-	35, 10, 19, 14	19, 14	35, 8, 2, 14	-		-	+	-	2, 18, 37	24, 35	7, 2, 35	34, 28, 35, 40	9, 14, 17, 15	-	35, 34, 38	35, 6, 4
9	Speed	2, 28, 13, 38	-	13, 14, 8	-	29, 30, 34	-	7, 29, 34	-	+	15, 28,	6, 18, 38, 40	35, 15,	28, 33, 1,	8, 3, 26, 14	3, 19, 35, 5	-	28, 30,
10	Force (Intensity)	8, 1, 37, 18	18, 13, 1, 28	17, 19, 9, 36	28, 10	19, 10, 15	1, 18, 36, 37	15, 9, 12, 37	2, 36, 18, 37	13, 28, 15, 12	+	18, 21, 11	10, 35, 40, 34	35, 10, 21	35, 10, 14, 27	19, 2		35, 10, 21
11	Stress or pressure	10, 36,	13, 29,	35, 10, 36	35, 1, 14, 16	10, 15,	10, 15,	6, 35, 10	35, 24	6, 35, 36	36, 35, 21	+	35, 4, 15, 10	35, 33, 2,	9, 18, 3, 40	19, 3, 27		35, 39,
12	Shape	8, 10, 29, 40	15, 10,	29, 34, 5,	13, 14,	5, 34, 4, 10		14, 4, 15, 22	7, 2, 35	35, 15,	35, 10,	34, 15,	+	33, 1, 18, 4	30, 14,	14, 26, 9,		22, 14,
13	Stability of the object's composition	21, 35, 2, 39	26, 39, 1, 40	13, 15, 1, 28	37	2, 11, 13	39	28, 10, 19, 39	34, 28, 35, 40	33, 15, 28, 18	10, 35, 21, 16	2, 35, 40	22, 1, 18, 4	+	17, 9, 15	13, 27, 10, 35	39, 3, 35, 23	35, 1, 32
14	Strength	1, 8, 40, 15	40, 26,	1, 15, 8, 35	15, 14,	3, 34, 40, 29	9, 40, 28	10, 15,	9, 14, 17, 15	8, 13, 26, 14	10, 18, 3,	10, 3, 18, 40	10, 30,	13, 17, 35	+	27, 3, 26		30, 10, 40
15	Duration of action of moving object	19, 5, 34, 31	-	2, 19, 9	-	3, 17, 19	-	10, 2, 19, 30	-	3, 35, 5	19, 2, 16	19, 3, 27	14, 26, 28, 25	13, 3, 35	27, 3, 10	+	-	19, 35, 39

3. List of Inventive Principles

40 Inventive Principles With Examples

Principle 1. Segmentation

A. Divide an object into independent parts.
   - *Replace mainframe computer by personal computers.*
   - *Replace a large truck by a truck and trailer.*
   - *Use a work breakdown structure for a large project.*

B. Make an object easy to disassemble.
   - *Modular furniture*
   - *Quick disconnect joints in plumbing*

C. Increase the degree of fragmentation or segmentation.
   - *Replace solid shades with Venetian blinds.*
   - *Use powdered welding metal instead of foil or rod to get better penetration of the joint.*

Principle 2. Taking out

A. Separate an interfering part or property from an object, or single out the only necessary part (or property) of an object.
   - *Locate a noisy compressor outside the building where compressed air is used.*
   - *Use fiber optics or a light pipe to separate the hot light source from the location where light is needed.*
   - *Use the sound of a barking dog, without the dog, as a burglar alarm.*

Principle 3. Local quality

A. Change an object's structure from uniform to non-uniform, change an external environment (or external influence) from uniform to non-uniform.
   - *Use a temperature, density, or pressure gradient instead of constant temperature, density or pressure.*

B. Make each part of an object function in conditions most suitable for its operation.
   - *Lunch box with special compartments for hot and cold solid foods and for liquids*

(Part C continued on the next page.)

C. Make each part of an object fulfill a different and useful function.
   - *Pencil with eraser*
   - *Hammer with nail puller*
   - *Multi-function tool that scales fish, acts as a pliers, a wire stripper, a flat-blade screwdriver, a Phillips screwdriver, manicure set, etc.*

Conflict in common language translated into TRIZ Parameter

Common Parameter	TRIZ Parameter	*Parameter number*
Force	Force	10
Damages	Object effected harmful factors	30

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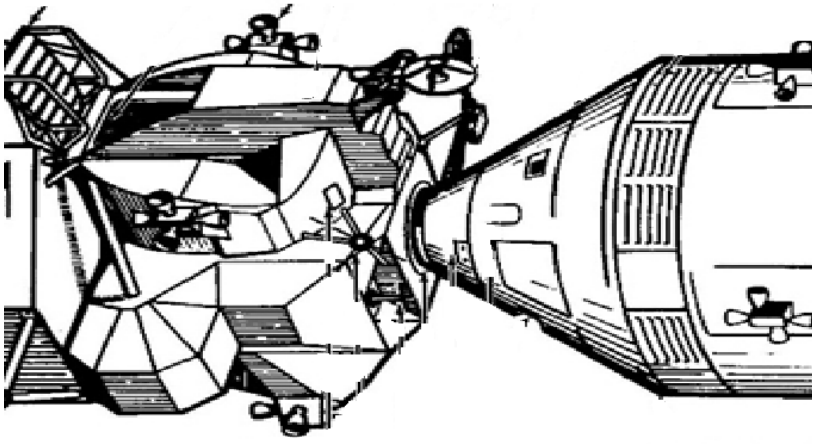
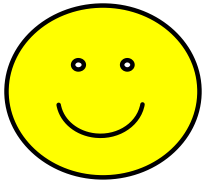
One key Apollo conflict – using TRIZ parameter

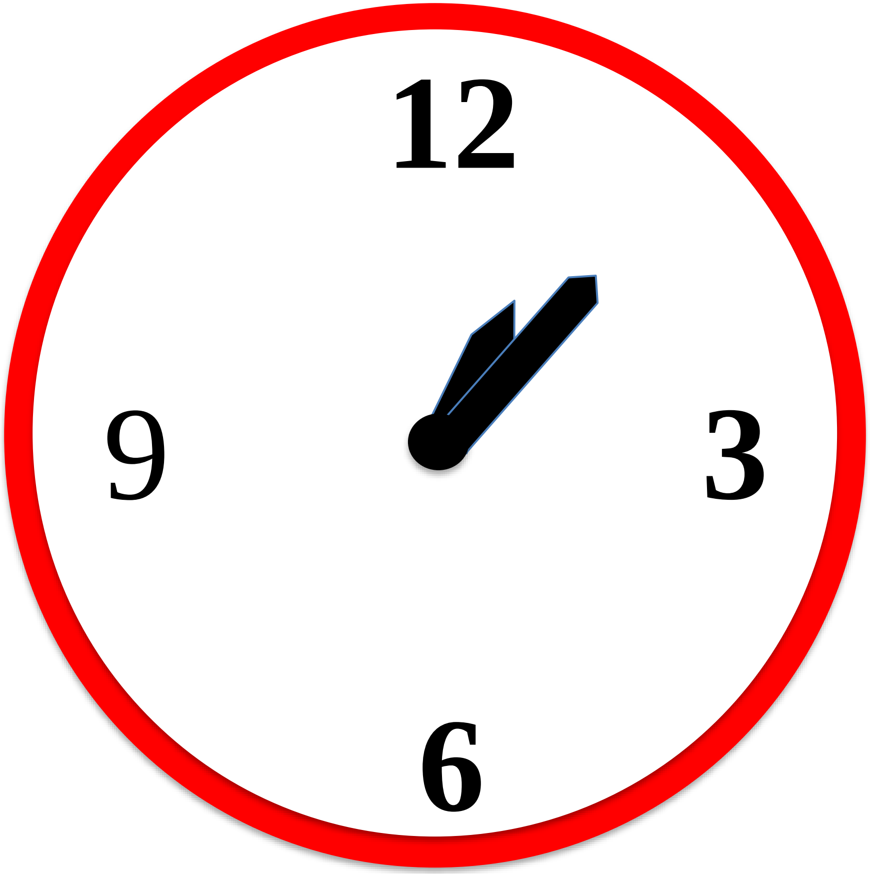


Force	
Object effected harmful factors	

Matrix results – the inventive principles

Worsening Feature Improving Feature		Object effected ahrmful factors
		30
10	**Force**	1, 35, 40,18

Return of Apollo 13



Apollo returned safely on the 17th of April 1970 at 1.07 pm

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