



competence centre
sustainable mobility and railways
innovation

A journey in transportation maintenance from earth to space



TRANSPORTATION SYSTEM

An aerial architectural rendering of a futuristic transportation hub. The scene features a complex network of roads, including a multi-lane highway on the left and a winding road through the center. Several modern buildings are scattered throughout, including a large, curved, glass-fronted structure in the center and a large, white, rectangular building with a flat roof on the right. Green spaces with trees and grass are interspersed among the buildings and roads. In the background, a large airport terminal with a curved roof and several aircraft on the tarmac is visible. The overall design suggests a highly integrated and efficient transportation system.

In future one system?

...

Non-motorized

Motorized private

Public Transport

Sea Transport

Air Transport

Space Transport

An aerial photograph of a winding asphalt road that snakes through a dense, lush green forest. The road has multiple sharp turns and is bordered by thick vegetation. A few vehicles are visible on the road. The image is overlaid with a semi-transparent red diagonal shape on the right side and a grey semi-transparent box at the bottom left.

TRANSPORTATION SYSTEM

ONE VISION

Share and improve

TRANSPORTATION SYSTEM

The background of the slide is a photograph of a snowy forest at night, with many bare trees standing in the snow. The sky above is dark and filled with numerous bright, diagonal streaks of light, resembling a long-exposure photograph of stars or a meteor shower. A large, semi-transparent red triangle is positioned on the right side of the slide, pointing towards the bottom right corner. The text is overlaid on this image.

Share experiences
Learn from similar industries
Collaborate
Become sustainable

Open Innovation

Competence centre msfi

**Canton of Ticino
City of Bellinzona
Swiss Federal Railway
University of Applied Sciences
and Arts of Southern
Switzerland**

Founding partners

msfi, refreshing technology.

Competence centre msfi

Project Management
Feasibility Studies
Consulting
Innovation management
Continuing education
Product development

What we do?

msfi, refreshing technology.

TRANSPORTATION SYSTEM

An aerial photograph of a dense railway network. Numerous tracks curve and intersect, with several passenger trains visible. The image is overlaid with a dark blue semi-transparent banner at the top and a large red semi-transparent triangle on the right side.

Topics

Mission

Equipment

Scheduling

Knowledge

Investments

Cost structure

Laws & Regulation

MAINTENANCE

A man wearing a yellow hard hat and a blue and white checkered shirt is depicted with multiple arms. He is holding a yellow level, a blue and red power drill, a hammer, and a wrench. The background is a solid grey color.

Definition

The process of preserving a condition or situation or the state of being preserved

The provision of financial support for a person's living expenses, [...]

Manus tenere

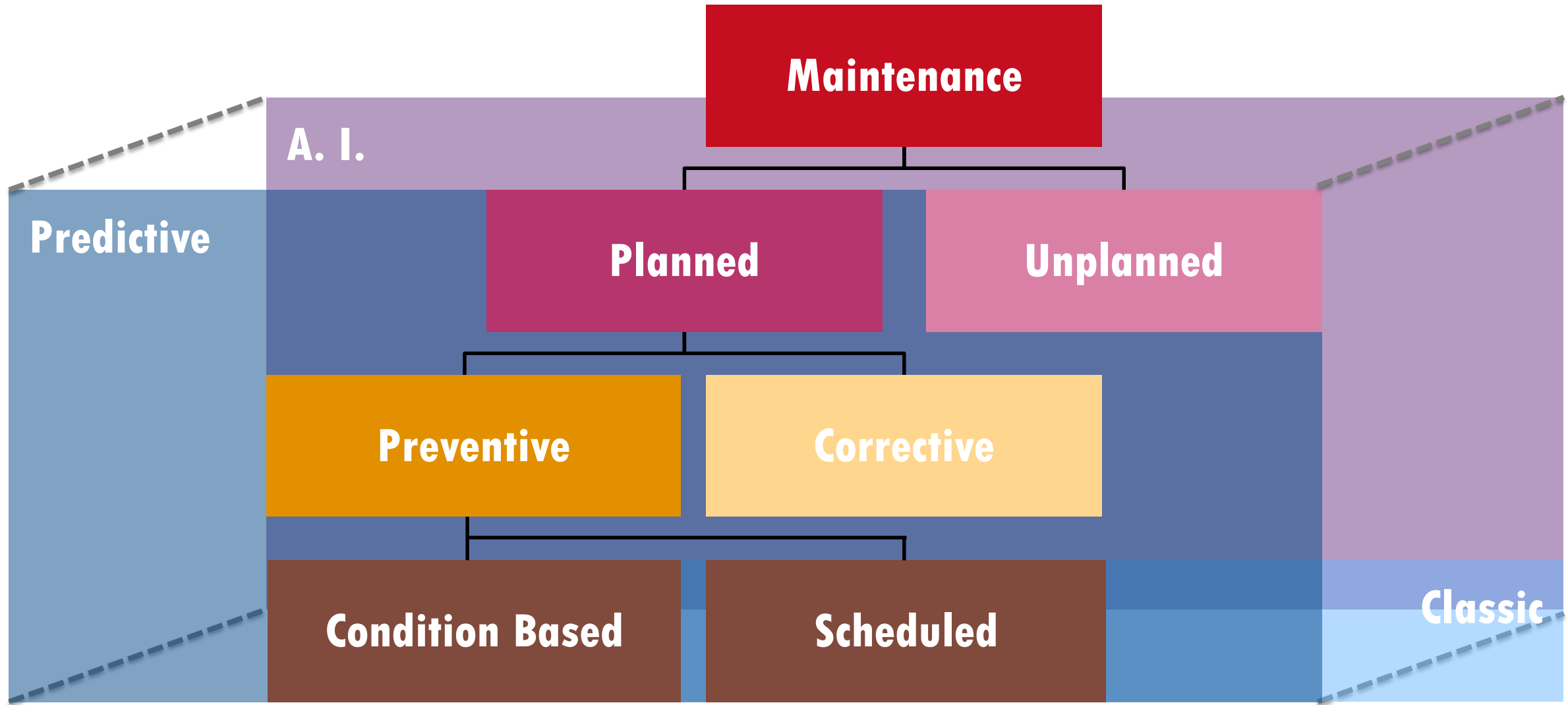
MAINTENANCE



Unplanned
Scheduled / Planned
Preventive
Corrective
On-Condition
Predictive / A.I.

Approaches

MAINTENANCE



Options

TECHNICAL ISSUES

A close-up photograph of a large commercial airplane engine, showing the fan blades and the engine casing. The engine is white and has a blue logo on the side. The background shows a tarmac with a white truck and some cargo. A large red diagonal overlay covers the right side of the image, containing a list of consequences. The text is in white, bold, sans-serif font.

Minor incidents

Accidents

Loss of lives

Loss of Equipment

Reputational damages

**Reduced quality
of service**

Consequences

TECHNICAL ISSUES

SAFETY!

Consequences

Minor incidents

Accidents

Loss of lives

Loss of Equipment

Reputational damages

**Reduced quality
of service**



THE OPERATOR VIEW

**Limit disruptions, delay,
cancellations**

High technical reliability

**Maintenance scheduling
supports the operations**

Costs conscious approach

Transportation System

MAINTENANCE DILEMMA



The CFO challenge: moving finance beyond a cost centre

The CTO defy: fast innovation changes and operations understanding

The CEO: pick great CFOs and CTOs

Cost – CAPEX & OPEX

NON-MOTORIZED TRAFFIC



Human powered mobility

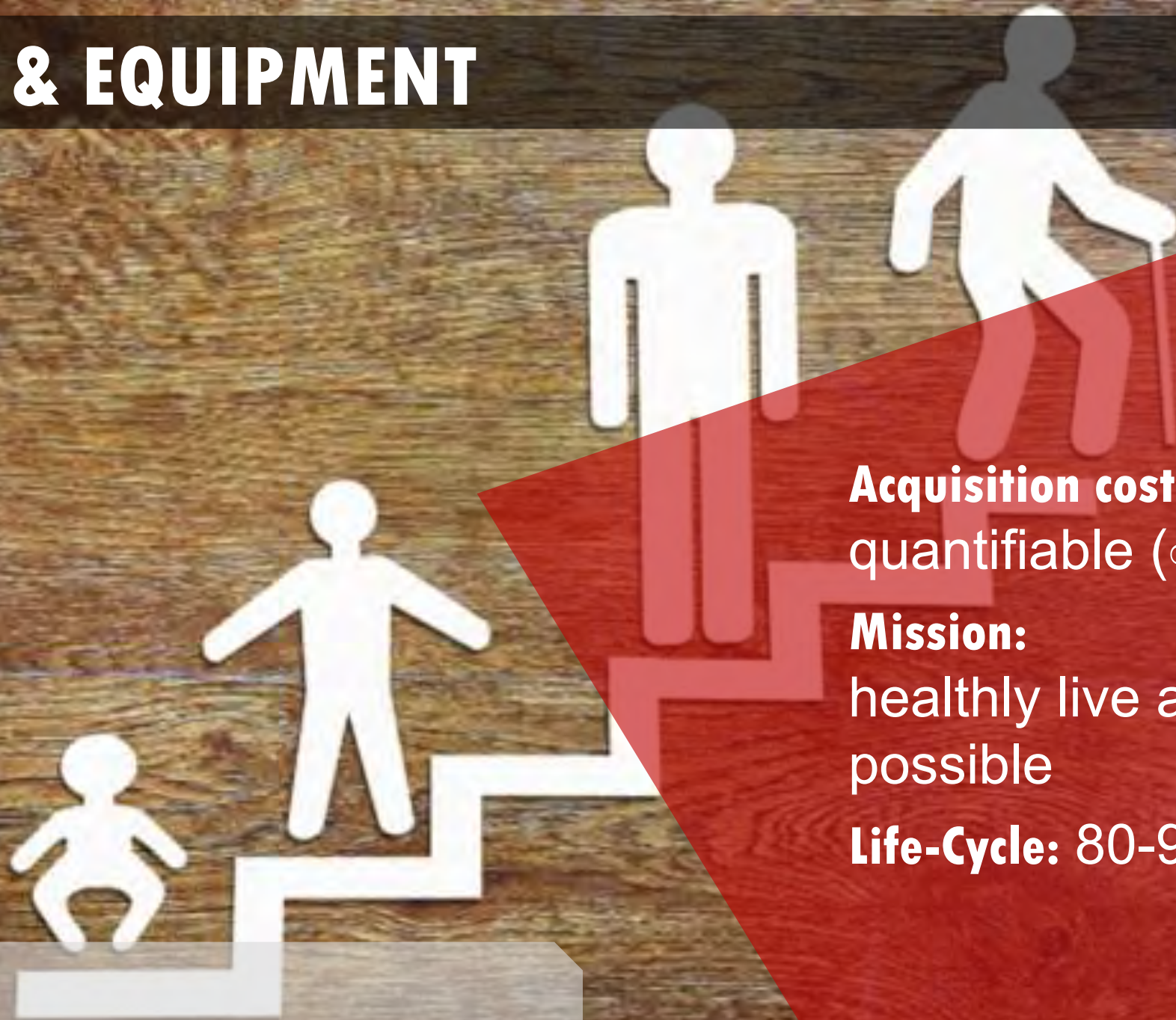


WALKING

Very short distance
No time constraint
Slowest system
Weather condition
Healthy*

Non-motorized Traffic

MISSION & EQUIPMENT



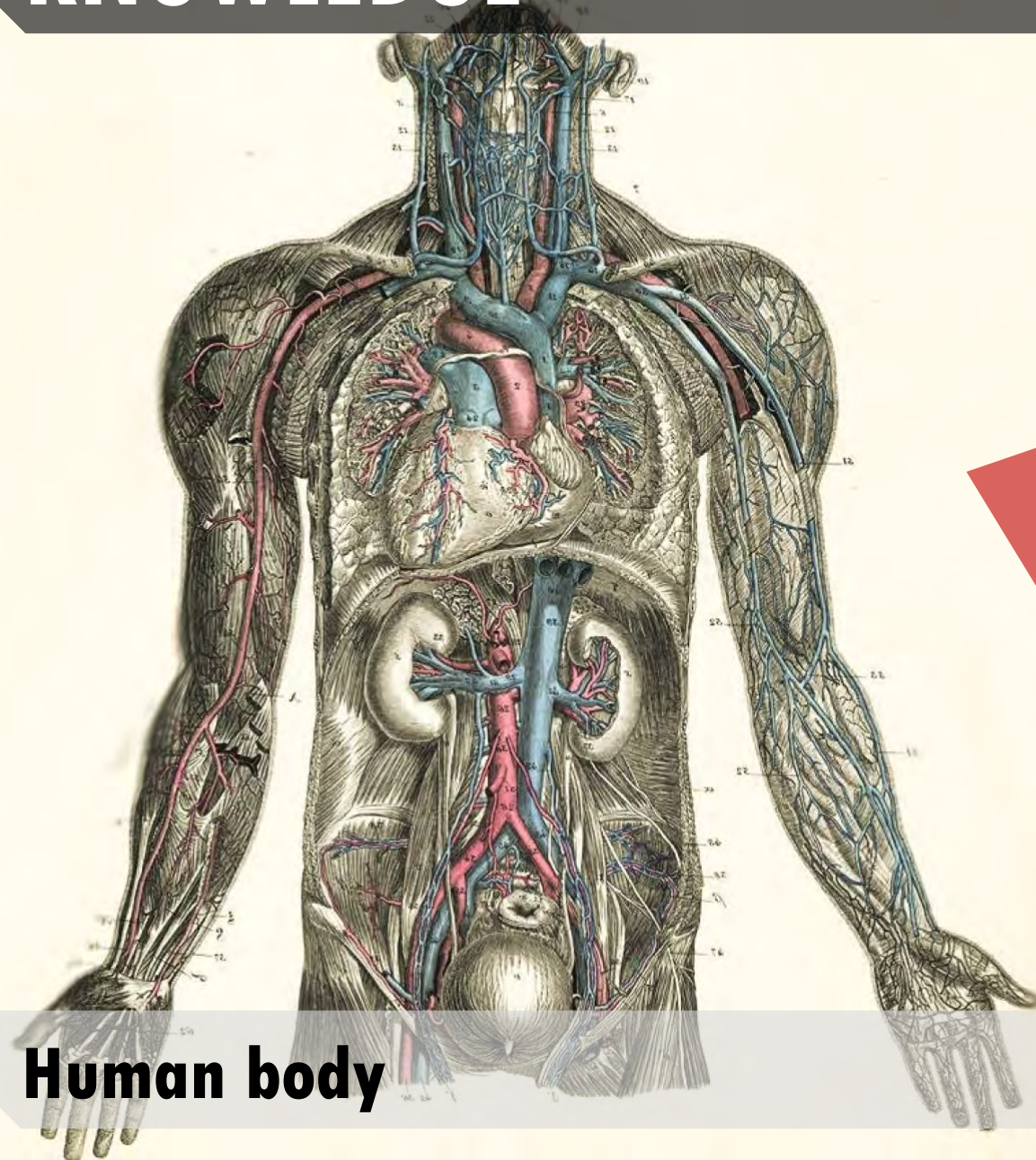
Acquisition costs: not quantifiable (∞)

Mission: healthy live as long as possible

Life-Cycle: 80-99 yr

Human body

KNOWLEDGE



Human body

**Very complex &
sensible system**

**Little or no margin
for errors**

**Years of Training
(University)**

MAINTENANCE

Human body

Patient Medical History

Physician _____

Office Phone _____

Yes ☐ No ☐

9. Are you allergic to or have you had reactions to:
Local Anesthetics (e.g. Novocain) _____
Penicillin or any other Antibiotics _____
Sulfa Drugs _____
Barbiturates _____
Sedatives _____
Iodine _____
Aspirin _____
Any Metals (e.g. nickel, m _____
Latex Rubber _____
Other (please list) _____

1. Are you under medical treatment now? _____
2. Have you ever been hospitalized for any surgical operation or serious illness within the last 5 years? _____
If yes, please explain _____

3. Are you taking any medication(s) including non-prescription medicine? _____
If yes, what medication(s) are you taking? _____

4. Have you ever taken Fen-Phen/Redux? _____

5. Do you use tobacco? _____

6. Do you use controlled substances? _____

7. Are you wearing contact lenses? _____

8. Do you or have you had any of the following?
Yes ☐ No ☐

High Blood Pressure _____
Heart Attack _____
Fever _____

Heart Disease _____
Cardiac Pacemaker _____
Heart Murmur _____
Angina _____
Frequently Tired _____
Anemia _____
Emphysema _____
Cancer _____
Arthritis _____
Prosthetic Placement or Implant _____
Diabetes _____
Disease _____

At least once a year
On condition, preventive
maintenance
Limited/no spares
Integrated sensors

Stroke _____
Hay Fever / Allergy _____
Tuberculosis _____
Radiation Therapy _____
Glaucoma _____
Recent Weight Change _____
Liver Disease _____
Heart Disease _____
Respiratory Disease _____
Miscellaneous _____

SCHEDULE




Immediate: life threatening situation

Mid-Short term: not life-threatening event

Long term: convenience or upon agreement

Human body

COSTS



Health insurance:
AVG 3'000 USD/yr*
**Expenditure per
inhabitant/month:**
780 USD
12,1% GDP (CHE)

Human body

NON-MOTORIZED TRAFFIC

A photograph of an orange mountain bike leaning against a brick wall. The bike is positioned diagonally, with its front wheel closer to the viewer. The frame is a vibrant orange, contrasting with the dark, textured brick wall. The bike features black handlebars, a black seat, and black tires with a knobby tread pattern. The background is a blurred brick wall, and the lighting is soft, creating a warm atmosphere.

Human powered mobility

NON-MOTORIZED TRAFFIC

Human (e)-powered mobility



NON-MOTORIZED TRAFFIC



Human e-powered mobility

MISSION & EQUIPMENT

An aerial photograph of a city, likely Paris, showing a dense urban layout with a river (the Seine) winding through it. A large red semi-transparent triangle is overlaid on the right side of the image, containing white text. The text describes the mission and equipment for a specific mode of transport.

Costs:

1'000 – 8'000 USD

Mission: transport of a person over a short distance

Life-Cycle: ~5 yr

Non-Motorized Traffic

KNOWLEDGE

Commuter Ready

Rear Rack Mount
Front Rack Mount
Fender Stay Mount
Front Rack/Basket Mount
Dual Kickstand Mounts

3 Frame Sizes

16.5" S/M Step Thru
17.5" Medium
19.0" Large

Minimal 4 - Button Display

Class 1, 2, 3 Regulations Adaptable
Thumb-Throttle Ready

Sporty Trigger Shifters

9 Speed w/Gear Window

Custom Lightweight Aluminum Fork

Standard Fork Travel Geometry
Drop-in Suspension Fork Upgradable
Quick Release

28 MPH Geared Motor

Super Lightweight
350 W: Nominal
500 W: OverBoost® Mode

High Definition Cadence Sensor

8.5 x Faster Response Time
104 Poles / Revolution
Torque Sensor Upgradable

High Performance Drivetrain

9 Speed Shimano Cassette

Total Weight

48.5 lbs
(22.0 kg)

Heavy Duty Wheels

12G Spokes
Double Walled Rim

High Performance Gearing

52T Front / 11T Rear
56T Upgradable

Upgradable Battery

7.8 Ah - 21 Ah Capacity
Removable Battery Pack
Up to 100 Miles Range
Fast 9A Recharge

180mm Disc Brakes

Shimano BR-M375

E-Bike Rated Tires

Wide 700 x 45C Tire
High Pressure Rim Strip
85 PSI Max

System complexity: low-mid complexity

Training: 3-4 years (college level) +

~1 year of specialization

Non-Motorized Traffic

MAINTENANCE

A close-up photograph of a red bicycle brake caliper mounted on a carbon fiber frame. The caliper is red with black text, including "10-B" and "00483". A black cable runs through the caliper. The background is blurred, showing more of the bike's frame and components. A large red diagonal overlay covers the right side of the image, containing white text.

Schedule: on condition or eventually yearly

Error Margin: high

Spares: widely avail.

Monitoring: none/low, increasing

Non-Motorized Traffic

COSTS



Typical components: Tyres, batteries, driving chains, brakes, gearshift

Operating: ~0

Maintenance:
<100 USD/year

Non-Motorized Traffic

MOTORIZED TRAFFIC



Fossil fuel powered mobility

MOTORIZED TRAFFIC



Fossil fuel powered mobility

MOTORIZED TRAFFIC



Hybrid powered mobility

MOTORIZED TRAFFIC



e-powered mobility

MISSION & EQUIPMENT



Costs: from 15'000 to 300'000 USD

Mission: Transport of persons and/or freight over a mid-long distance

Life-Cycle: ~5-15 yr

Fossil fuel powered mobility

KNOWLEDGE

The background of the slide is a photograph of an industrial welding process. A robotic arm, painted in a bright orange-red color, is shown in the process of welding a metal component. A large, intense blue and white flame is visible at the point of contact, with a dense spray of bright orange sparks emanating from it. The scene is set in a factory environment, with other industrial equipment and structures visible in the background, though they are out of focus.

System complexity: mid complexity

Training: 3-4 years (college level) + ~1 year of specialization

Motorized Traffic

MAINTENANCE

A person is holding a tablet that displays a 3D model of a vehicle chassis. The model has several blue lines and boxes highlighting specific components. The background is a blurred image of a train track with tracks and overhead wires.

Schedule: by distance or time (yearly)

Error Margin: medium

Spares: widely avail.

Sytem Monitoring:
integration with
connectivity started, incr.

Motorized Traffic

SCHEDULE

A white Tesla Model X is parked on a rocky shore at sunset. The car's falcon-wing doors are open, and the background shows a calm sea and distant mountains under a warm, orange sky. A large red diagonal graphic element is overlaid on the right side of the image.

Scheduled Maintenance

On condition, Pre-Trip,
30k km+

Tuning

Motorized Traffic

COSTS & COMPONENTS

A close-up photograph of a Volvo car's interior, focusing on the steering wheel and dashboard. The steering wheel is black with silver accents and features the Volvo logo in the center. The dashboard has a large, circular analog speedometer with a blue and red needle, flanked by digital displays showing fuel level and engine temperature. The background is a solid red color.

Typical components: Tyres, batteries, driving chains, brakes, gearbox

Operating:
up to 40'000 USD/year
in average ~15'000 USD/year

Maintenance:
~1500 USD/year

Motorized Traffic

PRIVATE/PERSONAL TRANSPORTATION

Regulations and Laws are present and enforced in a limited way

Equipment Technical condition is a personal responsibility

In case of incident or accidents, government may issue fines and insurances reduce coverage

Innovation technology acceleration

Personal mobility

“Mass products”

Mass mobility

Fully customized product

National and international

regulations and standards rules the technical and operational aspects

Innovative disruption is entering the market

Accidents, Incidents may lead to lawsuits, reputational damages, operational instability, loss of customer

PUBLIC/MASS TRANSPORTATION

URBAN PUBLIC TRANSPORTATION



Bus

LONG DISTANCE TRANSPORTATION



Long Range Bus

MISSION & EQUIPMENT



Costs: from 150'000 to 500'000 USD

Mission: Shared, partially sustainable transport of persons over a mid-long distance

Life-Cycle: 18+ yr

Bus / Long Range Bus

KNOWLEDGE

A shark is swimming through a large school of fish. The shark is orange and is positioned in the center of the frame, swimming towards the bottom. The fish are small and blue, forming a dense school around the shark. The background is a deep blue, suggesting an underwater environment.

System complexity: mid complexity

Training: 3-4 years (college level) +

~1 year of specializ.

Engineering: 3 years bachelor degree

Bus / Long Range Bus

MAINTENANCE



Bus / Long Range Bus

Schedule: distance & time, operator spec., national (sometimes) rules

Error Margin: medium

Spares: widely available

System Monitoring: integration with connectivity started, incr.



ARRIVA SCHEDULE

Scheduled Maintenance
Daily, Pre-Trip, Monthly
(or Weekly), 10k km+
Refurbishment (?)

Bus / Long Range Bus

COSTS



Typical components: Tyres, batteries, driving chains, brakes, gearbox

Operating:

~ 220'000 USD/year

Maintenance:

~10% Operating costs

Bus / Long Range Bus

URBAN PUBLIC TRANSPORTATION



Tram

URBAN PUBLIC TRANSPORTATION



Metro

MISSION & EQUIPMENT



Costs: 2m to 6.5m USD

Mission: sustainable transport of persons over a short distance, shared, infrastructure required

Life-Cycle: 30+ yr

Tram / Metro

TRM

URBAN PUBLIC TRANSPORTATION



S-Bahn

PUBLIC TRANSPORTATION



Train

PUBLIC TRANSPORTATION



High Speed Train

MISSION & EQUIPMENT



Costs: from 4m up to 40m USD

Mission: sustainable transport of persons over a mid-long distance

Life-Cycle: 40+ years

Refurbishments

Railway System

KNOWLEDGE



System complexity: medium
Training: 3-4 yr. college +
1-2 yr. specialization
Engineering: 4 yr. Master +
other spec.

Railway System

MAINTENANCE

Public Transportation

Schedule: distance & time,
operator specifications,
Service, Heavy maint. ->
50k, 100k, 500k, 1.0m
2m, 4m, 6m, 12m

Error Margin: medium

Spares: widely avail.

Monitoring: med+

COSTS

Typical components:
engine, electrical &
electronics comp.,
mechanical repairs,...

Maintenance:
1-6 USD/km

Railway System

SEA TRANSPORTATION



Cruise Ship

SEA TRANSPORTATION



Cargo Vessel

MISSION & EQUIPMENT



Costs: from 20'000'000 to 1'500'000'000 USD

Mission: shared transport of persons over a long distance

Life-Cycle: 35+ yr

Sea Transportation

KNOWLEDGE



System complexity: high
Training: 3-4 yr. college + 2 yr. experience + 2 yr. specialization
Engineering: 3-4 yrs. Bachelor/Master + other spec.

Sea Transportation

MAINTENANCE

An aerial photograph of a shipyard. In the foreground, a large red and white ship is docked at a pier. A blue crane is positioned over the ship. In the background, another large ship is docked, and a blue crane is also visible. The water is greenish-brown. The sky is blue. A red diagonal overlay covers the right side of the image.

Schedule: distance & time, operator spec., national requirements

Error Margin: medium

Spares: widely avail.

Monitoring: med+

Sea Transportation

SCHEDULE



Scheduled Maintenance

Pre-Trip Checklist, voyage repairs, monthly, yearly, 2.5 year, 5 year

Dry-docking and sea-docking

Refit & Conversions

Sea Transportation

AIR TRANSPORT



Helicopter

AIR TRANSPORT



Commercial Aircraft

MISSION & EQUIPMENT



Costs: from 50m to 440m USD

Mission: Shared, partially sustainable transport of persons or freight over a long distance

Life-Cycle: 12+ yr

Commercial Aircraft



KNOWLEDGE

System complexity: high to very high.

Training: 3-4 yr. college + 2-3 yr. experience + 2-3 yr. specialization

Engineering: 4 yr. Master + other spec.

Commercial Aircraft



MAINTENANCE



Commercial Aircraft

Schedule: distance & time,
international & national
requirements,
manufacturer recommend.,
operator spec.

Error Margin:
low to very-low

Spares: widely avail.

Monitoring: med+

SCHEDULE



Scheduled Maintenance:
Daily, Weekly, A-/C-
Checks, HMTV, Special
ground times, Mandatory
unplanned activities.

Refurbishments:
~6 years

Commercial Aircraft

SCHEDULE

A large commercial airplane engine is being worked on in a hangar. Two technicians are visible near the engine, which is mounted on a yellow support structure. The hangar is large and industrial, with a high ceiling and various equipment visible in the background. A red diagonal overlay covers the right side of the image, containing text about maintenance schedules.

Scheduled Maintenance:
Time Limited Parts,
Cycles

Life Limitation:
Time LLP reached, scrap

Engine / LDG

SCHEDULE

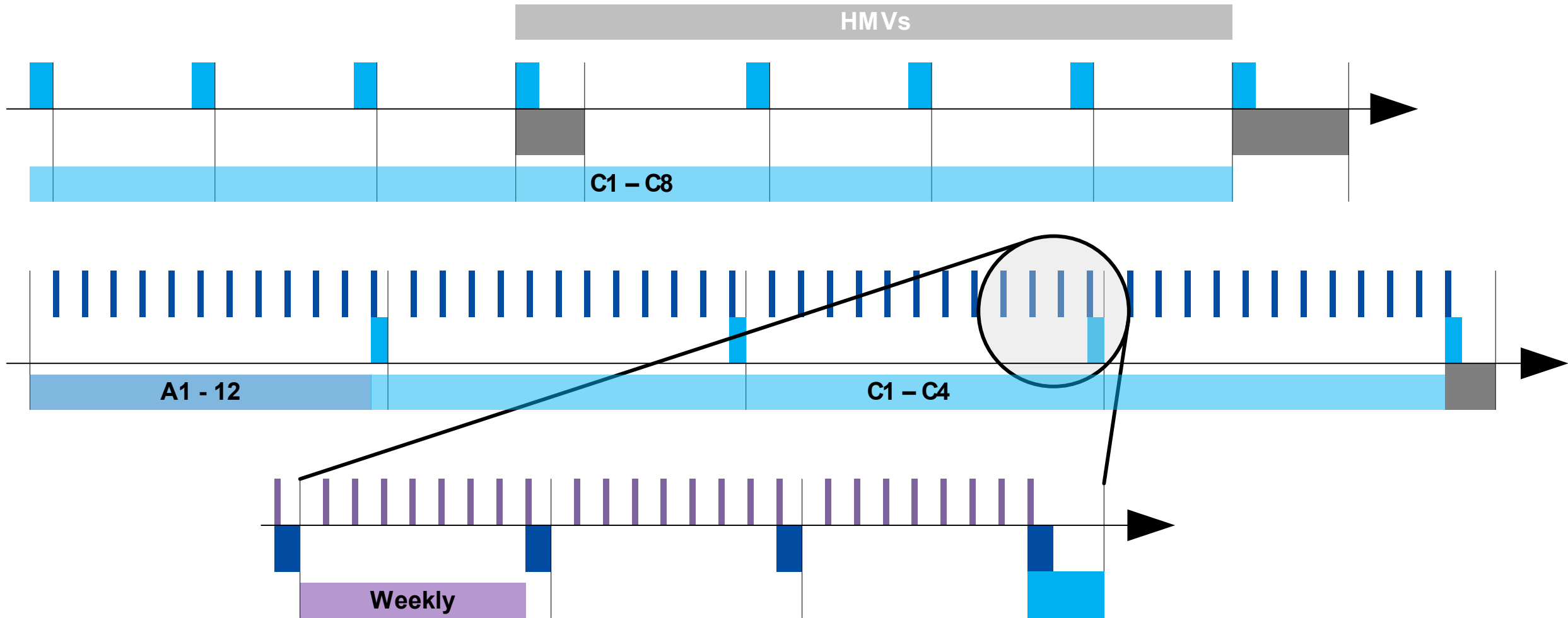
Maintenance to avoid incidents!

Maintenance to assure operational stability!

Maintenance for an efficient

Commercial Aircraft / Engine

SCHEDULE EXAMPLE



Commercial Aircraft

COSTS



Typical components: Tyres, Engines, Avionics, Structure, Brakes, Electrical systems, Communication...

Operating (WB):

~ 9'500 USD/FH (up to 17'000)

Maintenance:

Commercial Aircraft

PUBLIC/MASS TRANSPORTATION

Accidents, Incidents may lead to lawsuits, reputational damages, operational instability, loss of customer

Innovative disruption is entering the market

National and international regulations and standards rules the technical and operational aspects

Fully customized product

Mass mobility

No error accepted

Exclusive at first

(like aviation in the sixties)

Safety & Risk Management driven

Suborbital and Space travel opens new opportunities and threats to the actual transportation industry

FUTURE TRANSPORTATION?

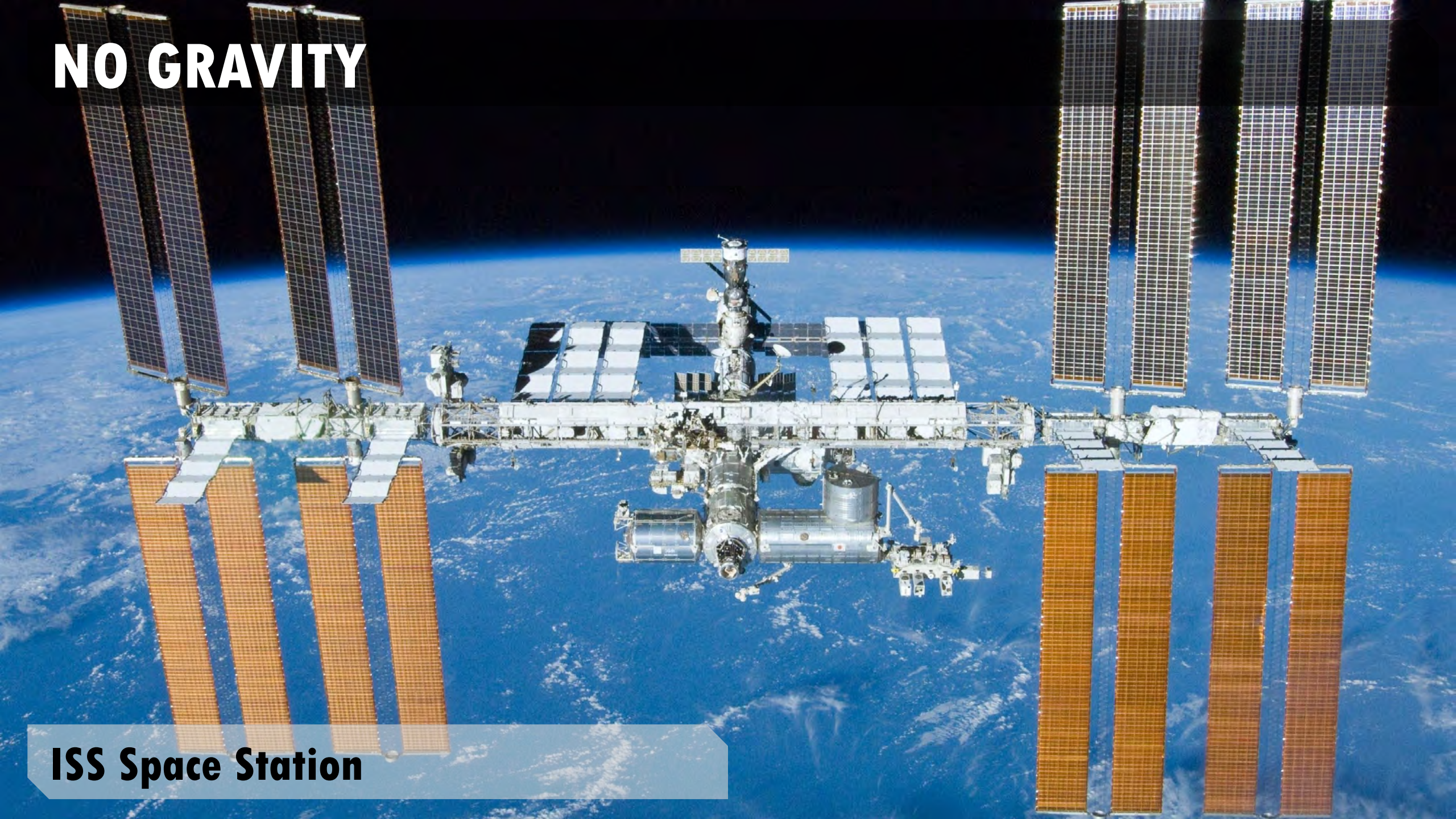
NO GRAVITY



Shuttle / Rocket

NO GRAVITY

ISS Space Station



MISSION & EQUIPMENT



Costs: ~ 210'000'000'000
USD (Shuttle program)

Mission: transport persons,
technical systems or
equipment into space

Life-Cycle: 30+ yr

No Gravity

KNOWLEDGE

System complexity:
very high

Training: 3-4 yr. college +
2-3 yr. experience +
2-3 yr. specialization

Engineering: 4 yr. Master +
PhDs

No Gravity

MAINTENANCE

A photograph of the Space Shuttle Columbia being mated to the External Tank and Solid Rocket Boosters in the Vehicle Assembly Building. The shuttle is white with red and black markings, and the boosters are red. Yellow cranes are visible lifting the assembly. A red semi-transparent overlay covers the right side of the image, containing maintenance-related text. A grey semi-transparent overlay is at the bottom left with the text 'No Gravity'.

Schedule: preventive only
Error Margin: none!
Spares: specific build
Monitoring: very high

No Gravity

SCHEDULE

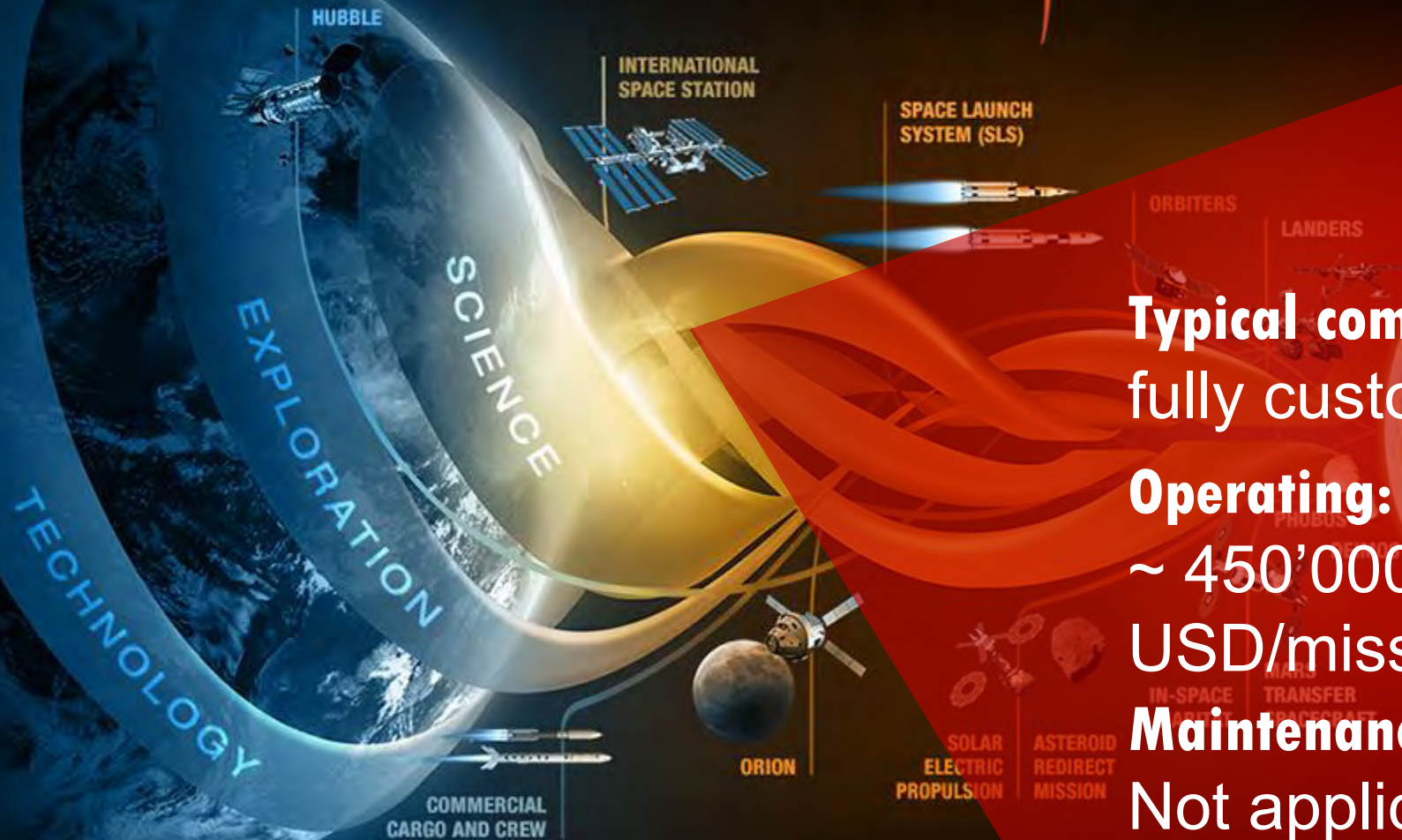
A large-scale industrial scene at night, showing the Space Shuttle Columbia being mated to the External Tank and Solid Rocket Boosters on the Mobile Launcher Platform (MLP) inside the Vehicle Assembly Building (VAB). The MLP is suspended by a yellow crane and is being moved by a large crawler-transporter. The scene is illuminated by bright overhead lights, creating a high-contrast environment. The background shows the complex steel structure of the VAB.

Scheduled Maintenance
Pre-mission (prepare)
After-mission (fixing)
Refurbishment:
after every mission

No Gravity

COSTS

JOURNEY TO MARS



Typical components:
fully customized systems

Operating:
~ 450'000'000
USD/mission

Maintenance:
Not applicable

No Gravity

SUMMARY


#	Type	Cost [k USD]	Range [km]	Speed [km/h]	Payload [# , TEU]	Mission [hr]	Life-Cycle [yr]	Utiliz. [%]	Utiliz. [hr]
1	Human	-	2	4	1	0.2	99	67%	16.00
2	Bike / Kickboard	6	9	20	1	0.5	5	5%	1.20
3	e-Bike	6	16	45	1	1	5	5%	1.20
4	Motorbike	24	28	120	1	1	20	5%	1.20
5	Car	158	1'501	120	4	2	15	8%	1.92
6	e-Car	108	251	120	3	2	10	8%	1.92
7	Bus	225	110	100	95	1.5	12	65%	15.60
8	LR Bus	340	2'300	100	60	8	20	70%	16.80
9	Tram	3'500	34	60	240	1	35	70%	16.80
10	Metro	4'750	31	100	1'000	0.5	30	70%	16.80
11	S-Bahn	6'000	53	160	1'000	1	40	60%	14.40
12	Regional Train	6'000	95	160	500	1.5	40	65%	15.60
13	IC Train	12'000	4'675	200	675	3	40	60%	14.40
14	High Speed Train	32'500	1'250	300	700	3	30	75%	18.00
15	Passenger Ship	761'500	5'250	42	4'000	72	35	75%	18.00
16	Vessel Container	127'500	11'959	35	16'000	480	35	75%	18.00
17	Helicopter	15'150	1'000	472	11	1	20	45%	10.80
18	Aircraft	245'000	7'250	900	450	10	25	76%	18.24
19	Space/Suborbital	255'000	130'050'000	28'000	2	168	30	0.05%	0.01

HIGHLIGHTS



Similar approach
Safety, protect
Scheduling
On-Condition

OVERVIEW – MAINTENANCE EXP.



Non-motorized	1.9hr/day	Closed to zero
Motorized private	1.9hr/day	2.2 USD/hr (~1'500 USD/yr)
Public Transport	16hr/day	95 USD/hr (~2'300 USD/day)
Sea Transport	16hr/day	-
Air Transport	16hr/day	900 USD/hr
Space Transport	>0.01 hr/day	>100'000'000 USD/miss.

SUSTAINABILITY = FUTURE



The background of the slide is an aerial photograph of a densely packed urban area, likely a city center, showing a complex network of buildings, streets, and green spaces. A large, semi-transparent red geometric shape, resembling a stylized 'M' or a large triangle, is overlaid on the right side of the image. The text is white and positioned in the upper left and lower right areas.

msfi FOR YOU

Our services for you:

Master of Advanced
Studies in Railways and
Sustainable Mobility
SUPSI

New Mobility Platform
MobLab Conference

Engineering and
Consulting

MAINTENANCE

A night scene of a stone path with glowing yellow fireflies. A large red 'X' shape is overlaid on the image, with the text 'Maintenance is not only a cost!' on the left and 'Maintenance is a Service!' on the right.

**Maintenance is not
only a cost!**

**Maintenance is a
Service!**

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