



KIVI / DOT

Space for Subsea

**Saturation Diving,
the Final Space Frontier?**

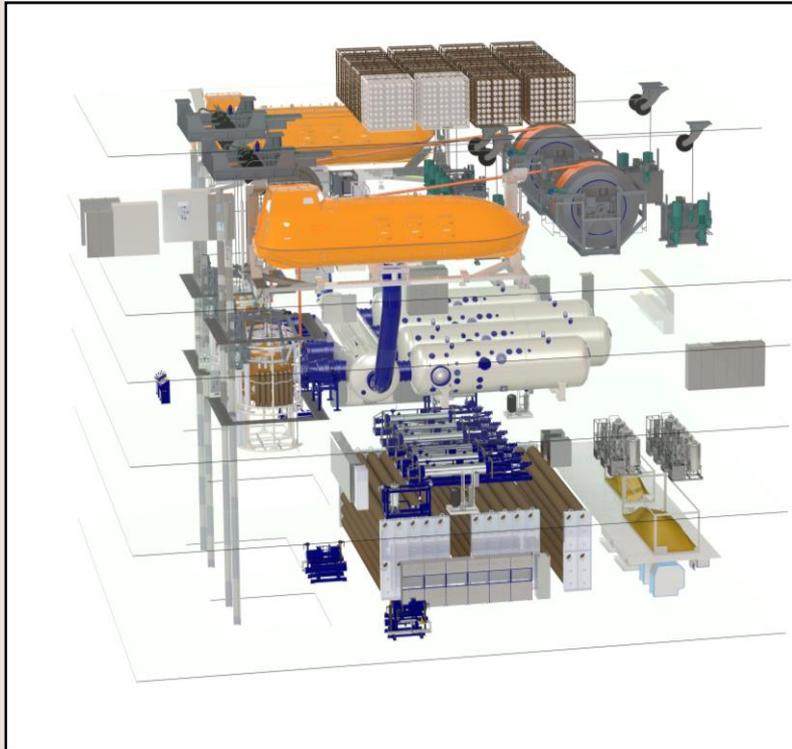
Johan de Bie, Royal IHC

IHC Hytech – KIVI-DOT Subsea-Space 2016 V 3-0

The technology innovator.

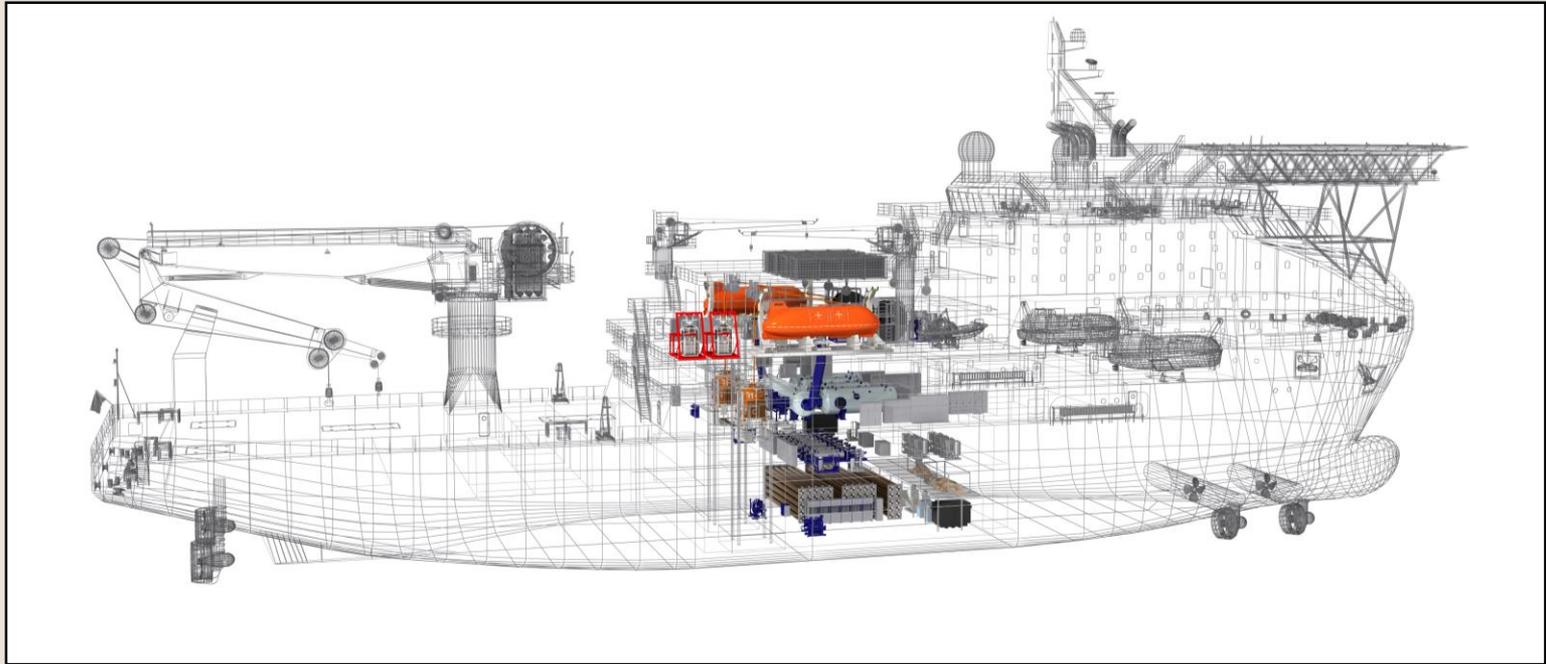


A place to live ; Comparison





A place to live ; Part of a larger structure



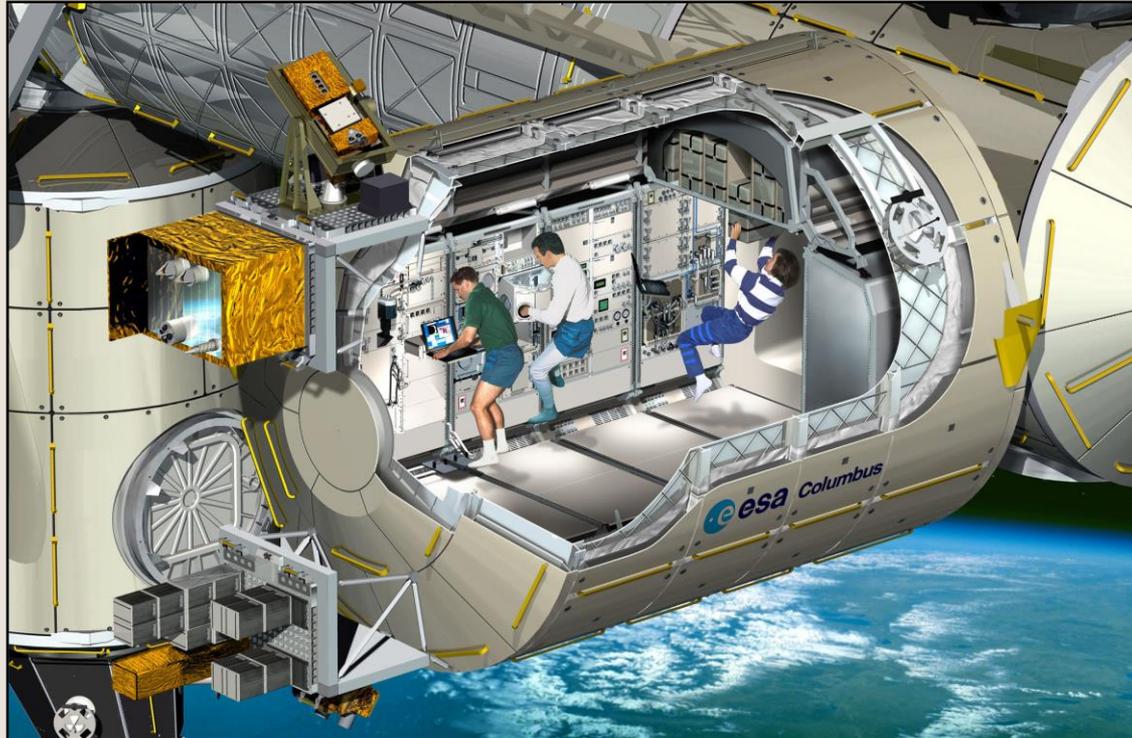


A place to live ; Saturation system





A place to live and work ; ISS



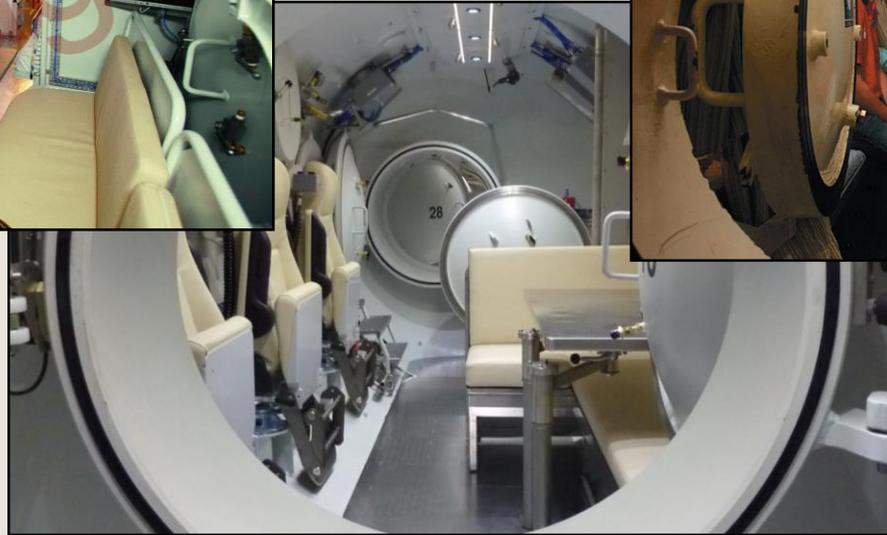


Inside the complex ; ISS





Inside the complex ; Saturation system





At work ; In the ISS



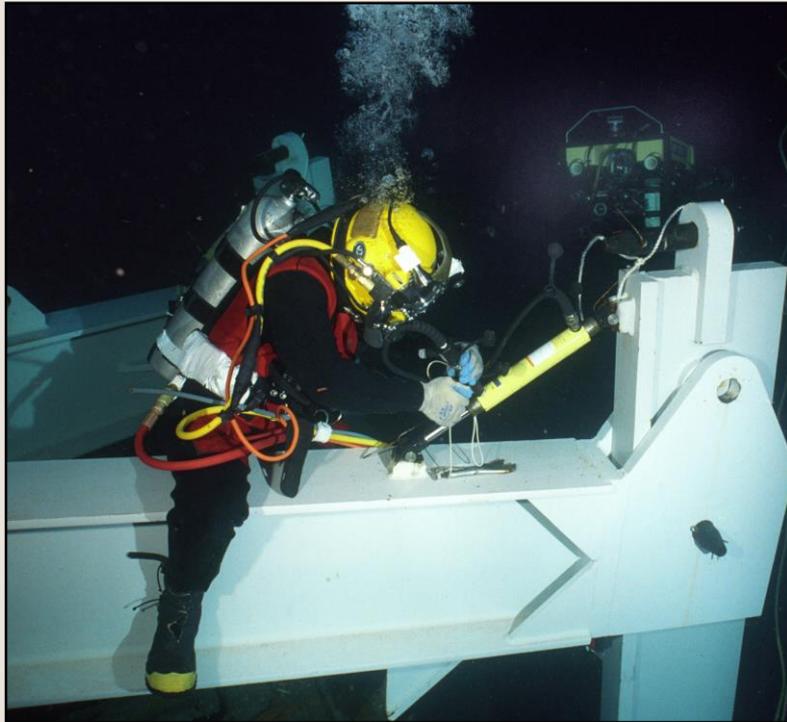


At work ; In the hostile environment





At work ; Equipment similarities



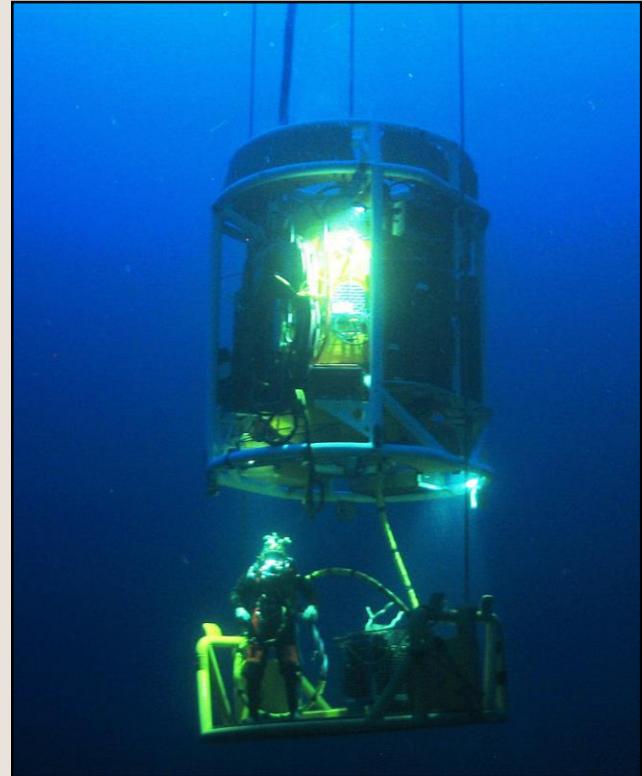


Getting to work ; Saturation diving bell



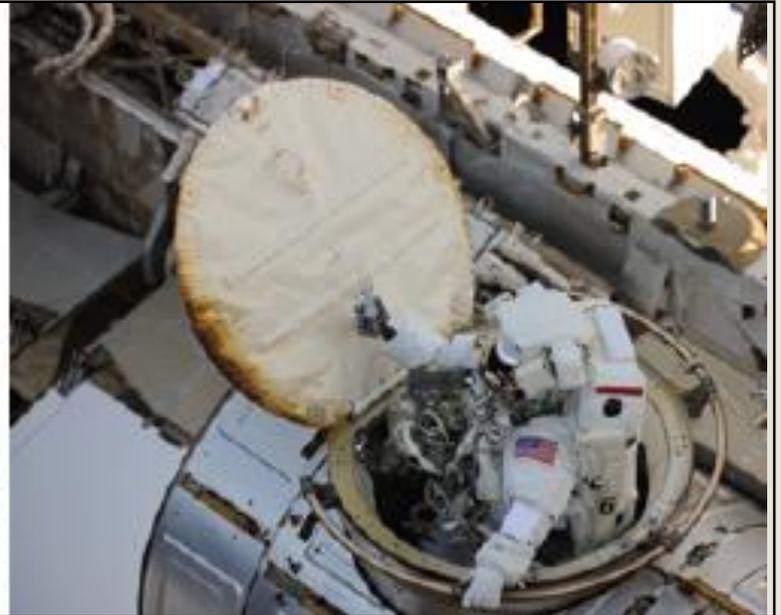


Locking out ; Saturation diving bell





Locking out ; ISS





Zero gravity ; Differences





Zero gravity ; Differences





Zero gravity ; Different cases





Going home ; Astronauts



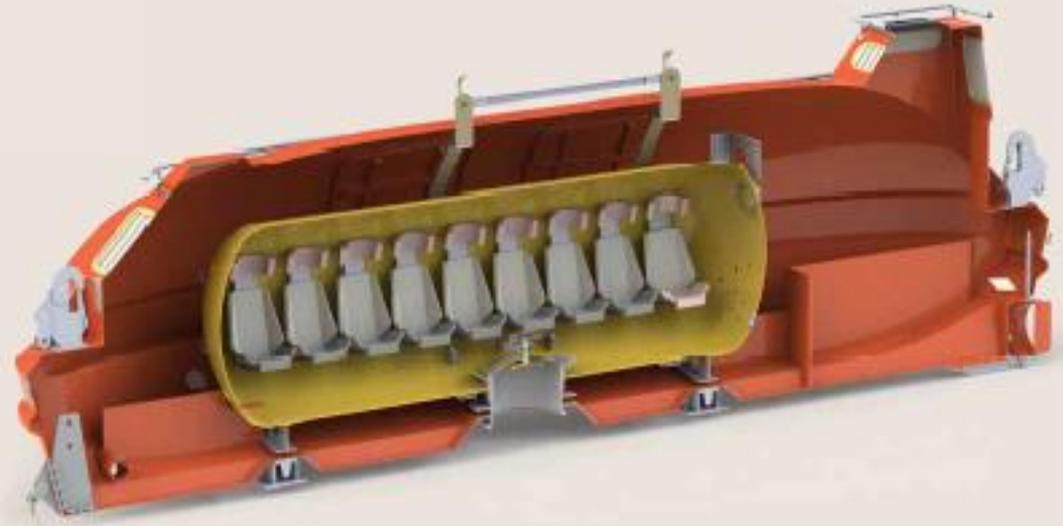
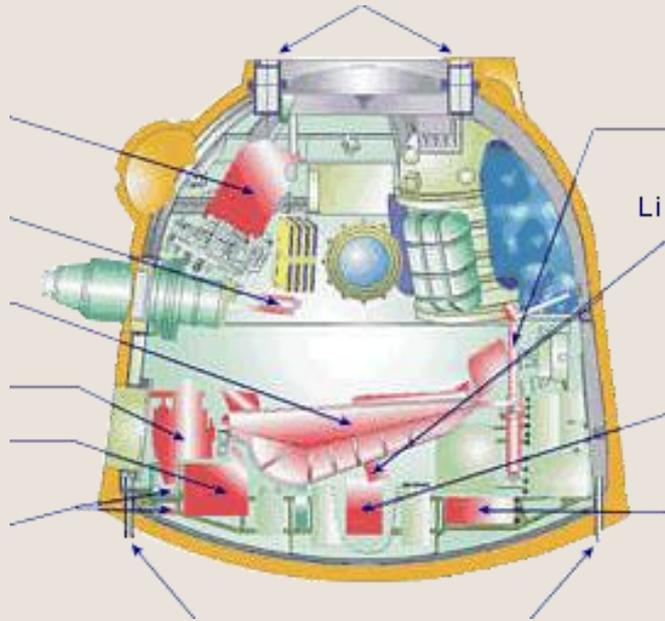


Going home ; Saturation divers





Emergency escape ; Concept





Emergency escape ; After use



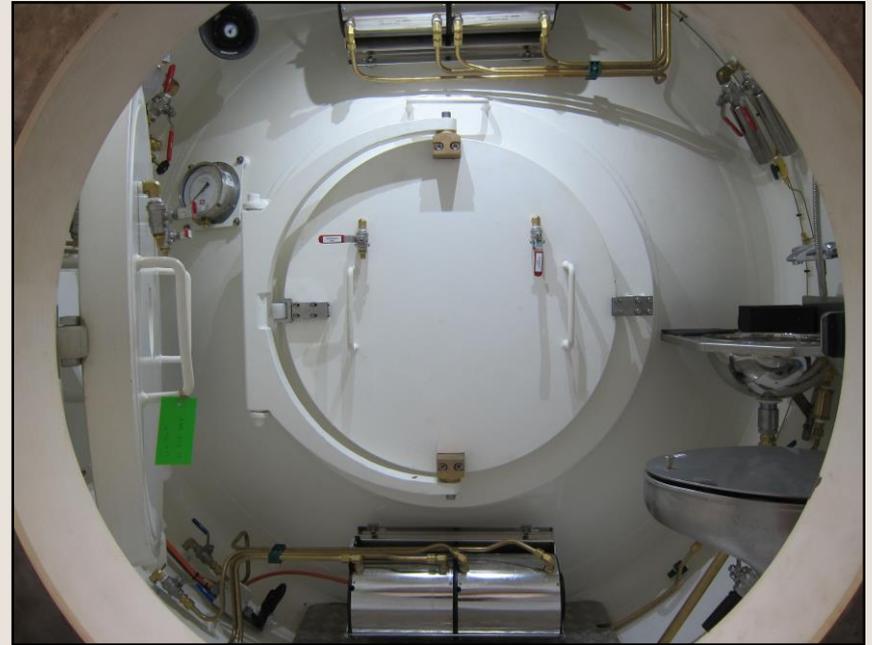


Construction ; Pressure vessel





Construction ; Hatches retaining pressure



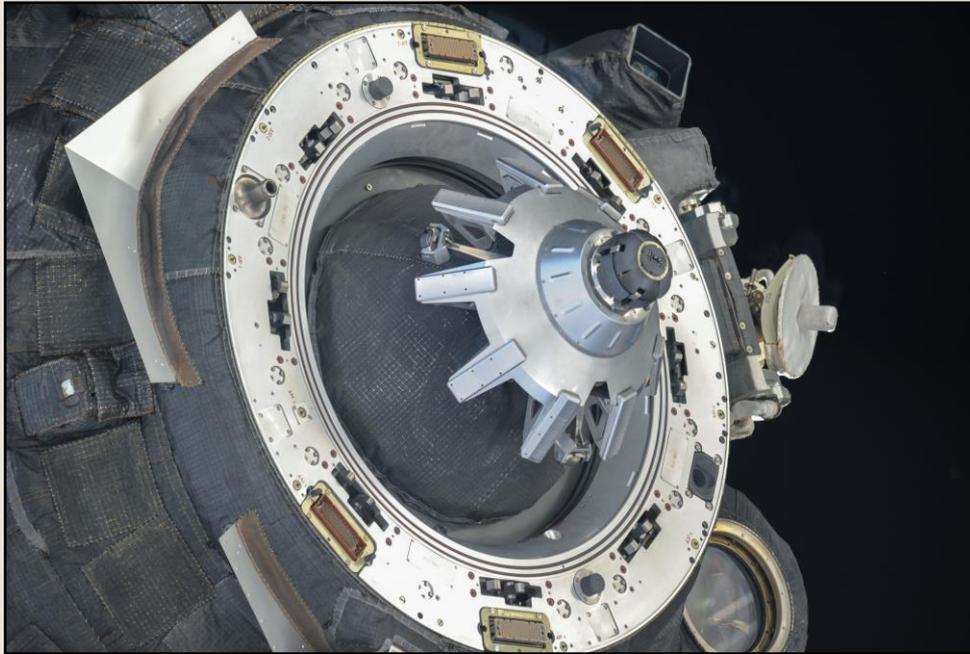


Construction ; Viewports



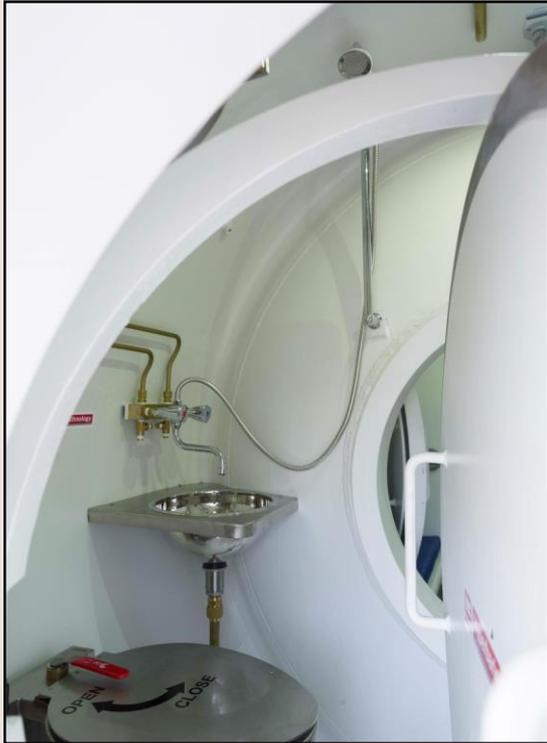


Construction ; Docking & Clamping





Construction ; Supporting life inside





Construction ; Supporting life inside





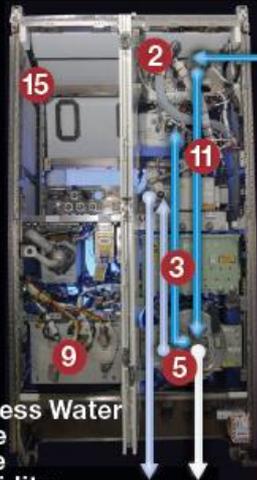
Construction ; Supporting life inside

U.S. Regenerative Environmental Control and Life Support System (ECLSS)

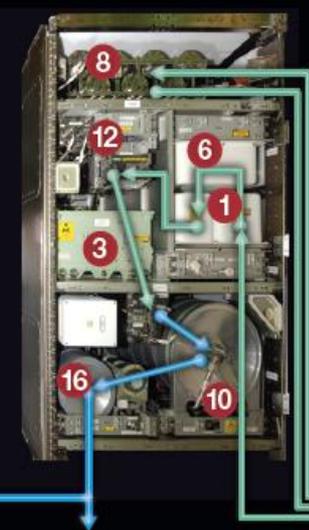
- | | | | |
|----|-----------------------|----|---|
| 1 | Catalytic Reactor | 12 | Reactor Health Sensor |
| 2 | Deionizer Beds | 13 | Storage Tanks |
| 3 | Digital Controller | 14 | Urine Processor Pumps |
| 4 | Distillation Assembly | 15 | CO ₂ Reduction System (Sabatier) Stack |
| 5 | Electrolysis Cell | 16 | Water Processor Delivery Pump |
| 6 | Gas Separator | 17 | Water Processor Pump & Separator |
| 7 | Multifiltration Beds | 18 | Water Processor Wastewater Tank |
| 8 | Particulate Filter | | |
| 9 | Power Supply | | |
| 10 | Product Water Tank | | |
| 11 | Pumps & Valves | | |

- | | | | | | |
|--|---|-----------------------------|--|---|---------------------|
| | = | Oxygen | | = | Process Water |
| | = | Hydrogen (vented overboard) | | = | Urine Brine |
| | = | Potable Water | | = | Humidity Condensate |

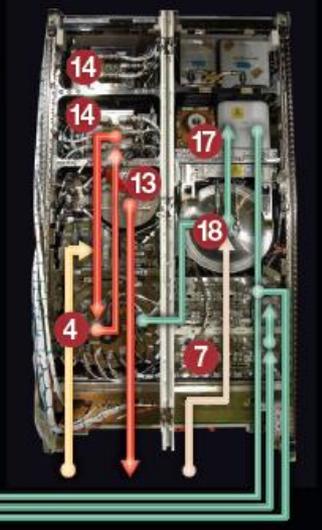
Oxygen Generation System (OGS) Rack



Water Recovery System Rack 1 (WRS-1)



Water Recovery System Rack 2 (WRS-2)





Construction ; Supporting life inside





Construction ; Supporting life inside



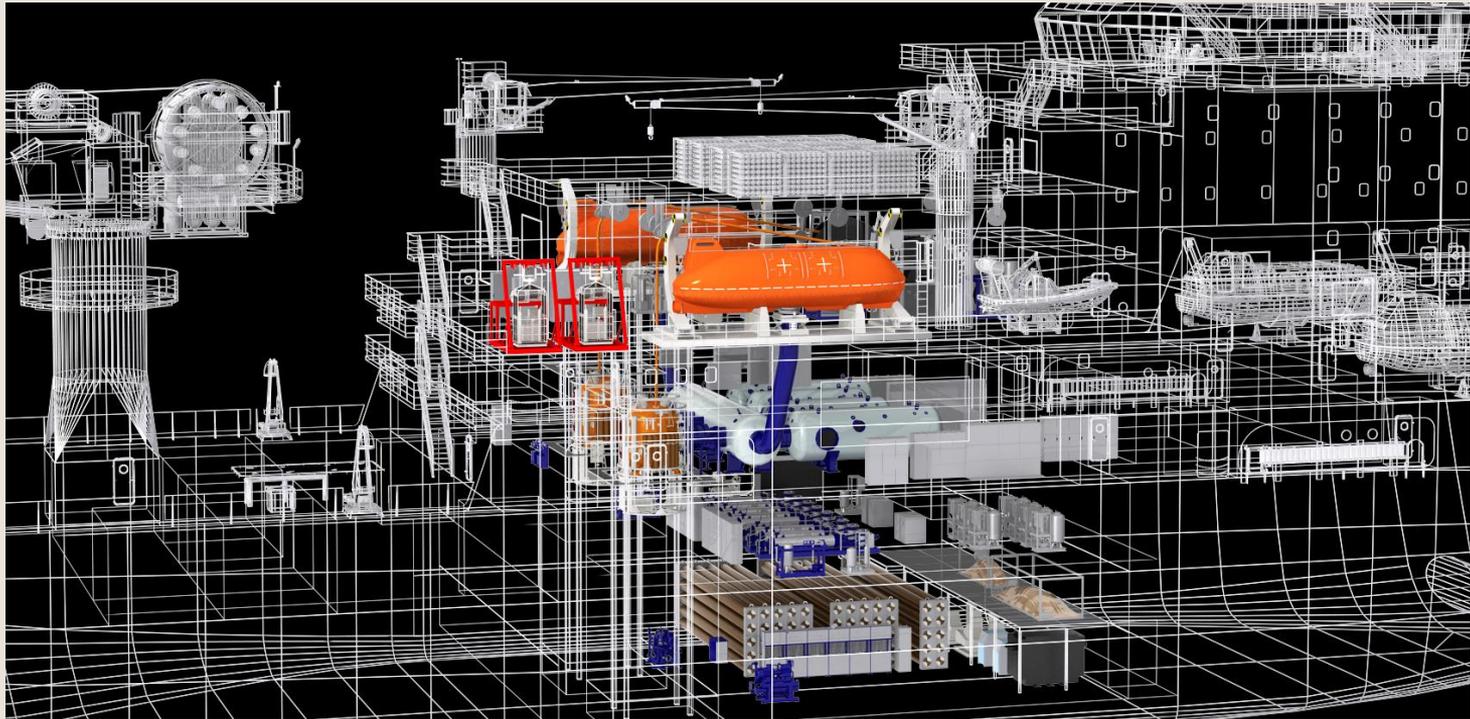


Construction ; Supporting life inside





Construction ; Supported from vessel





Construction ; Supported from earth





Construction ; Control rooms





Construction ; Control rooms





Breathable (livable) atmosphere

Dangers surrounding a typical breathable atmosphere:

Fire: Fire risk increases with higher Oxygen content

Pressure: Pressure differences cause decompression

Toxicity: Higher (pp) Oxygen content becomes toxic

Narcotic: Higher (pp) Nitrogen content becomes narcotic

CO₂: Exhaled CO₂ build up in enclosed environments

Contaminants: Contaminants build up in enclosed environments



Breathable atmosphere

Dangers surrounding a typical breathable atmosphere:

Moisture: Moisture is a danger when living in enclosed environments

Bacteria: Bacteria and germs can grow more easy in enclosed env.

Particles: Debris, rubble, spills etc. can create dangers in encl. env.

Temperature: Loss of body heat via breathing

WoB: Work of Breathing more dense gas causes fatigue



Breathable atmosphere

Space station:

Normal air at atmospheric pressure

Standard: 21% Oxygen (balance Nitrogen) @ 1 bar absolute

Saturation diving:

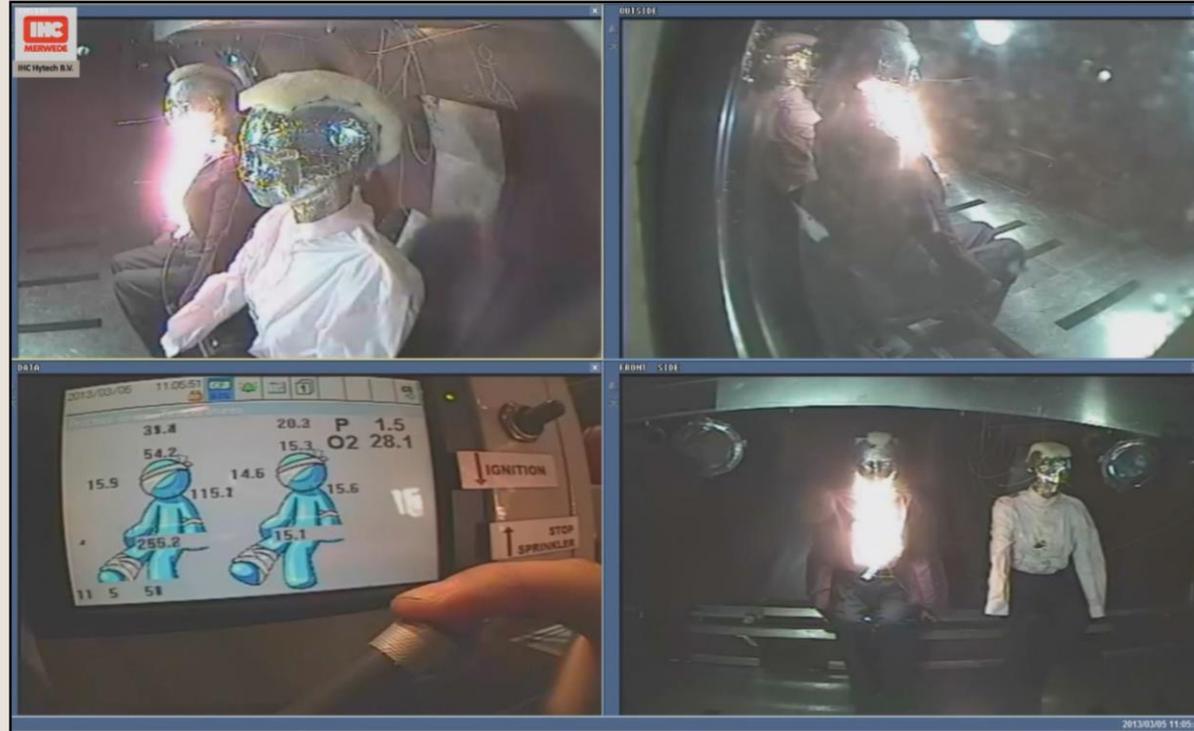
Heliox mixture with 0,4 ppO₂ at required depth

Example: 2% Oxygen (balance helium) @ 190 msw (20 bar absolute)

Breathable atmosphere

Fire risk increases massively with higher Oxygen content

Also increases with enclosed spaces which can't be evacuated fully or of which life is dependent





Breathable atmosphere

Suppressing fire
by extinguishing
with:

Water
(foam / spray / mist)

gas
(CO₂ / other)

or other means





Breathable atmosphere

Contamination
of breathing
gas caused
by fire





Breathable atmosphere

NASA conducting fire tests live in space

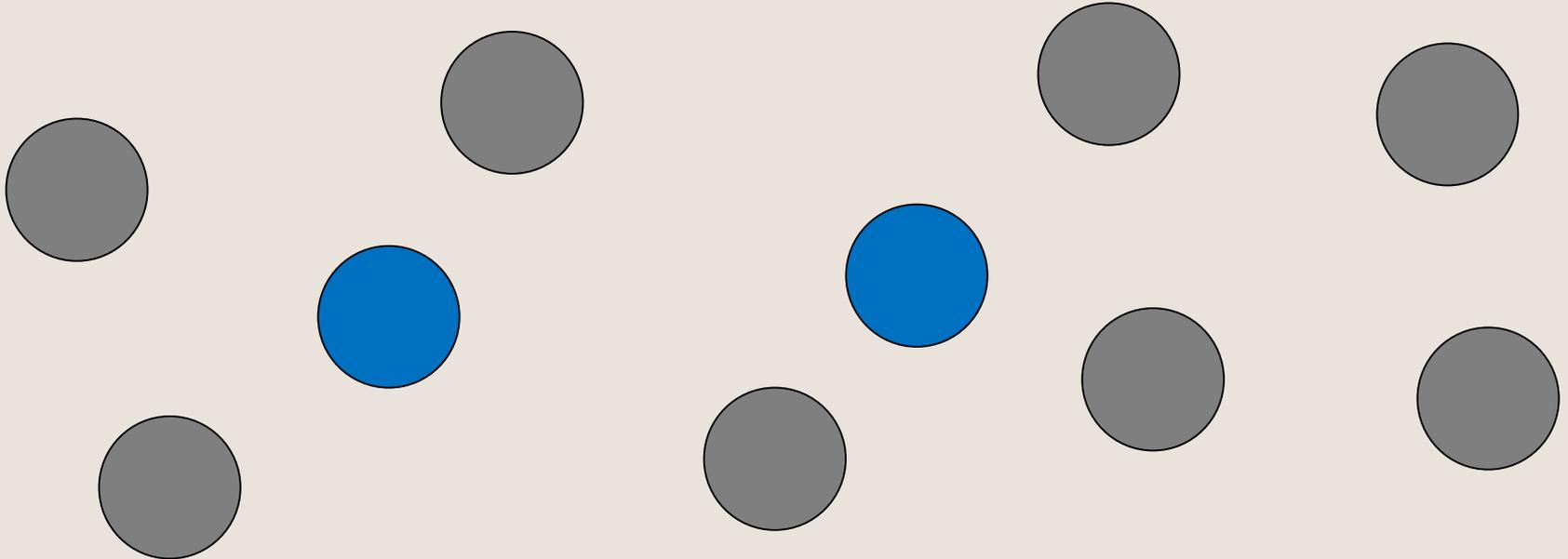
Saffire tests onboard the Cygnus craft





Breathable atmosphere

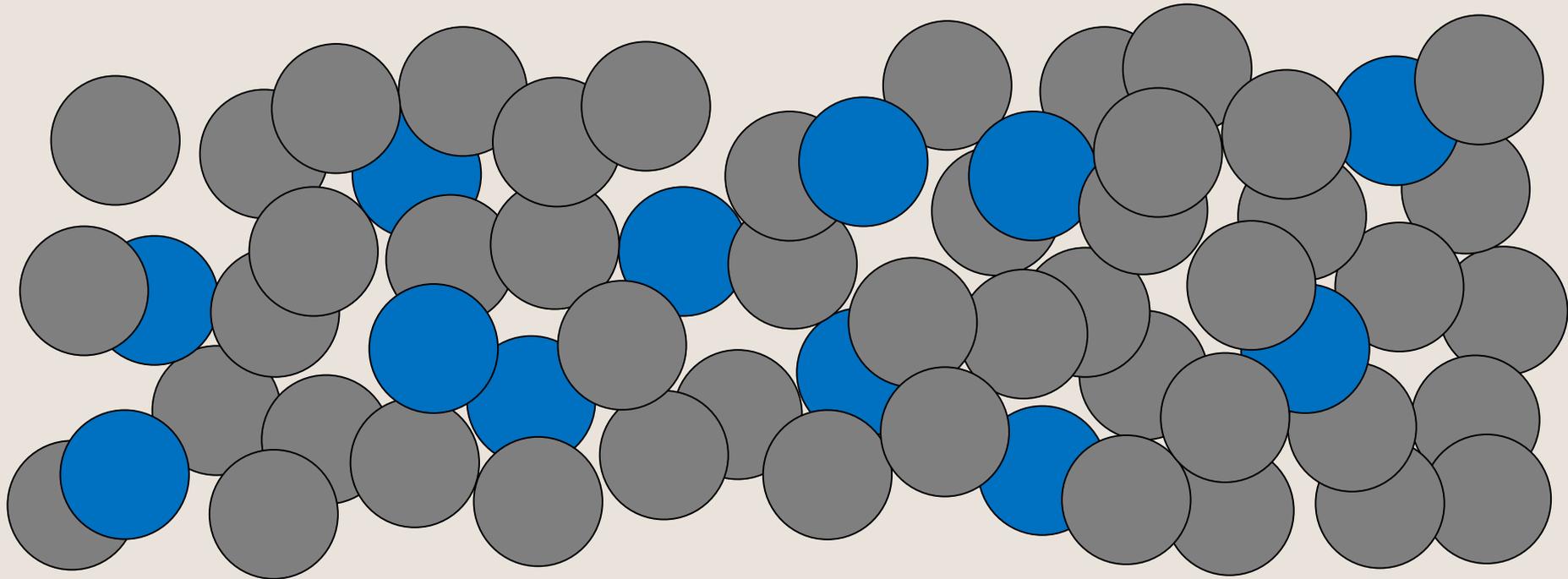
Normal air at atmospheric pressure





Breathable atmosphere

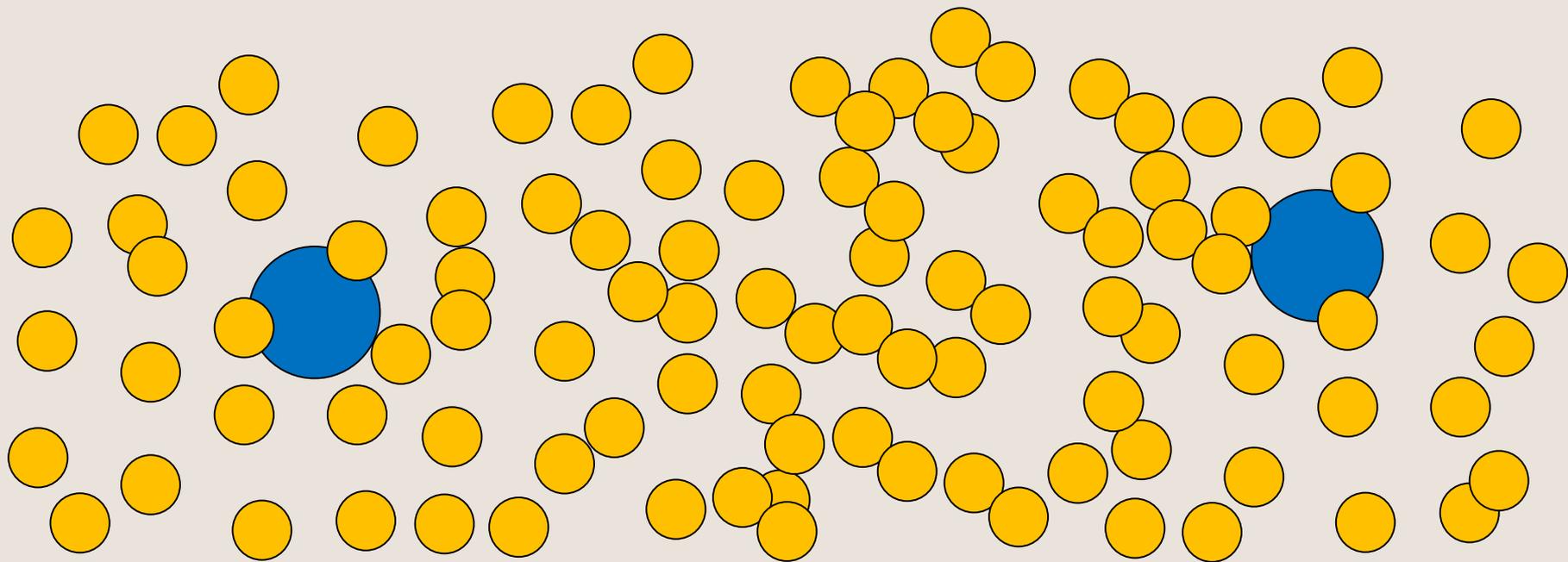
Normal air at 50 msw (6 bar absolute)





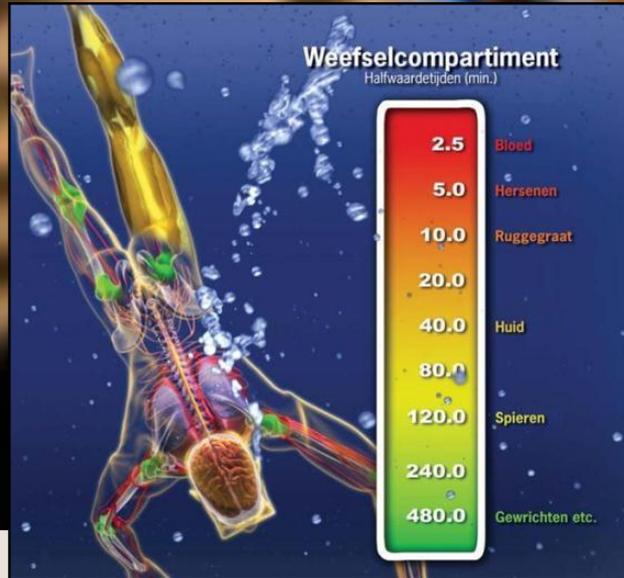
Breathable atmosphere

Heliox with 2% Oxygen at 190 msw (20 bar absolute)



Breathable atmosphere

Decompression (DSI) when exposed to different pressures



M.	12	15	18	21	24	27	30	33	36	39	NEW GROUP
FT.	40	50	60	70	80	90	100	110	120	130	
7	6	5	4	4	3	3	3	3	3	3	◀ A
123	74	59	41	31	22	19	12	9	6	5	◀ B
25	21	17	15	13	11	10	10	9	8		◀ C
105	59	38	30	22	14	12	5				
37	29	24	20	16	16	14	13	12	11		◀ D
93	51	31	25	17	9	8					
49	38	30	26	23	20	18	16	15	13		◀ E
81	42	25	19	12	5	4					
61	47	36	31	28	24	22	20	18	16		◀ F
69	33	18	14	7							
73	56	44	37	32	29	26	24	21	19		◀ G
57	24	11	8								
87	66	52	43	38	33	30	27	25	22		◀ H
43	14										
101	76	61	50	43	38	34	31	28	25		◀ I
29	4										
116	87	70	57	48	43	38					◀ J
14											
138	99	79	64	54	47						◀ K
161	111	88	72	61	53						◀ L

TABLE 3 – REPETITIVE DIVE TIMETABLE

∞ LIGHT FACE NUMBERS ARE RESIDUAL NITROGEN TIMES (RNT)
∞ BOLD FACE NUMBERS ARE ADJUSTED MAXIMUM DIVE TIMES (AMDT) –



Breathable atmosphere

Oxygen toxicity

pO_2 (bar)	Time to cause 10% lung damage	Time to cause 20% lung damage
2.0	9 hours	15 hours
1.5	13 hours	20 hours
1.0	23 hours	Several days
0.8	Several days	
0.6	No damage	

Nitrogen narcotic starts at pN_2 of 3,2 bar (as of 30 msw)



Breathable atmosphere

CO₂ production by the human body:

Under normal working conditions metabolic usage of a human is 0,5 ltr/min of pure Oxygen

Results in production of 0,5 ltr/min of pure CO₂

Does not change under pressure !

Must be removed from atmosphere, toxic



Breathable atmosphere

CO₂ removal:

**By scrubbing
with sodalime,
lithium hydroxide
or molecular
sieves**

**Alternatives being
developed**



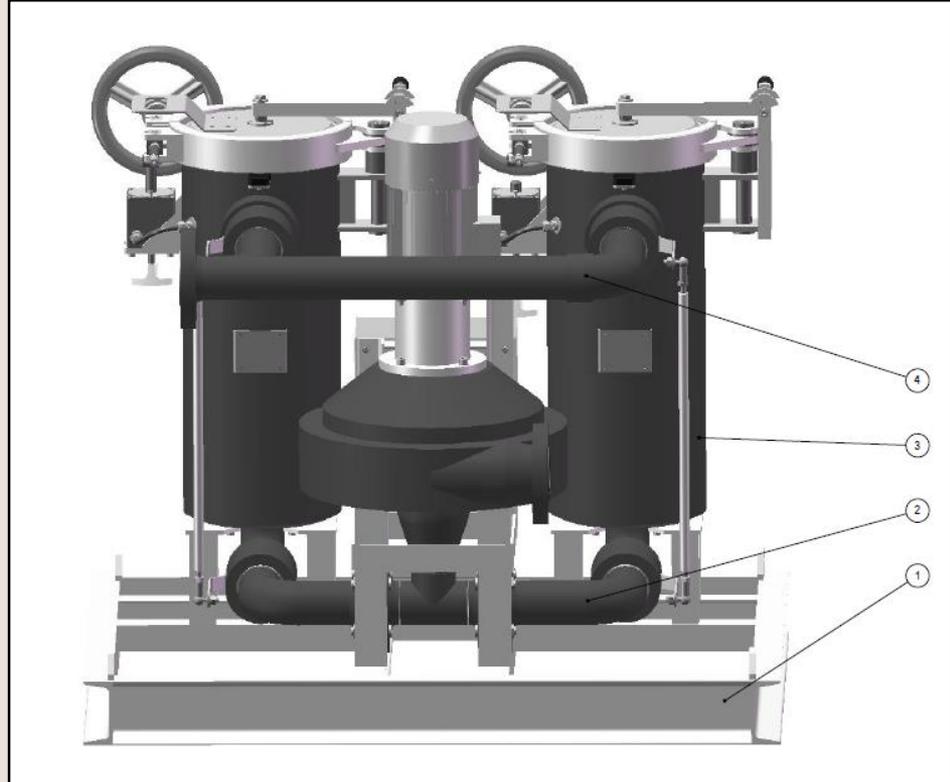


Breathable atmosphere

CO₂ removal:

**By scrubbing
with sodalime,
lithium hydroxide
or molecular
sieves**

**Alternatives being
developed**





Breathable atmosphere

De-Contamination:

**By scrubbing
with blended carbon
molecular sieves
and catalists**

**Removes pollution
due to breathing,
vomit, urine, feces,
sweat etcetera**

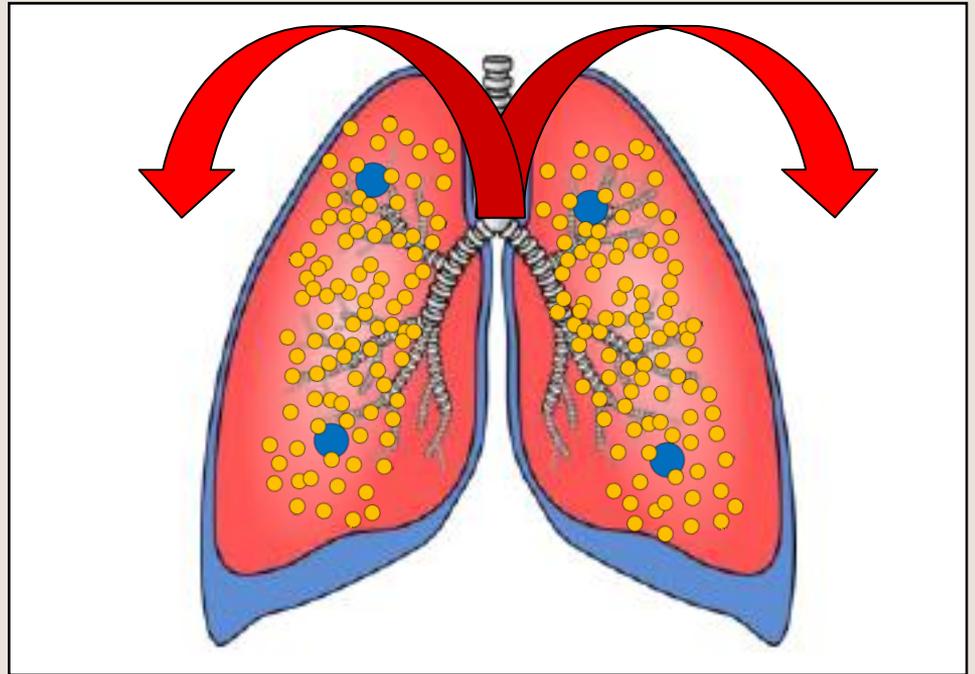




Breathable atmosphere

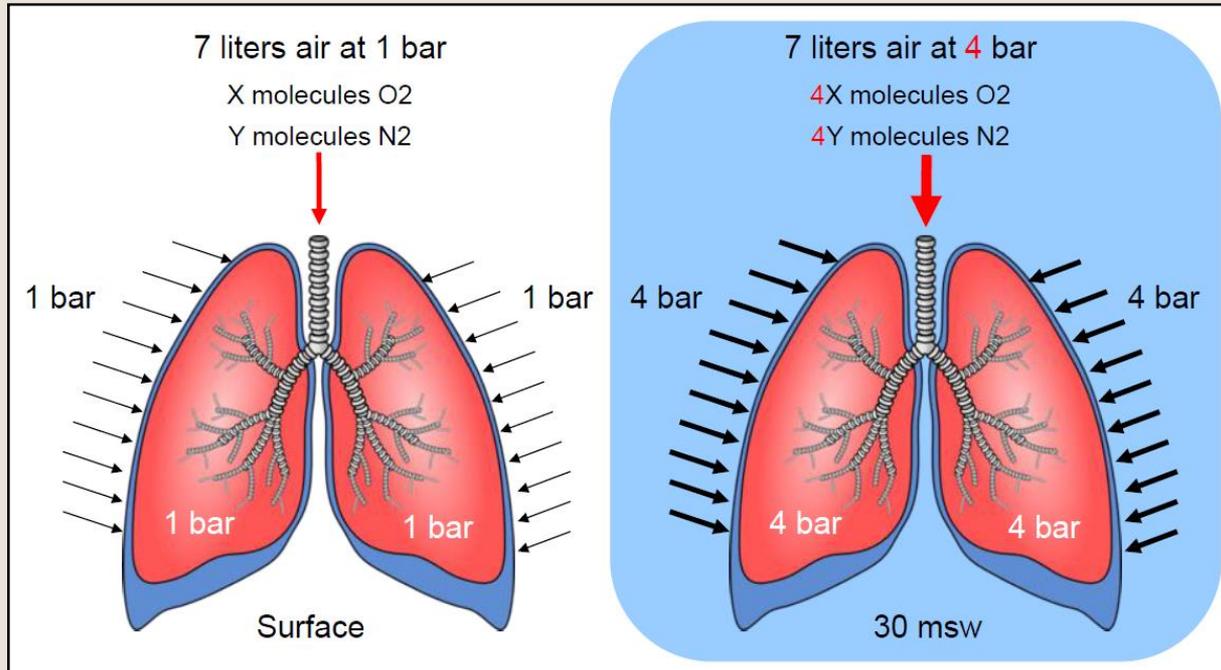
**Loss of body heat
via breathing,
helium accelerates**

**Higher local
temperatures
inside a saturation
dive system
in order to prevent
hypothermia**



Breathable atmosphere

Work of Breathing, much more breathing gas handled





Breathable atmosphere

Lost particles present a hazard:

Contamination

Malfunction

Obstruction

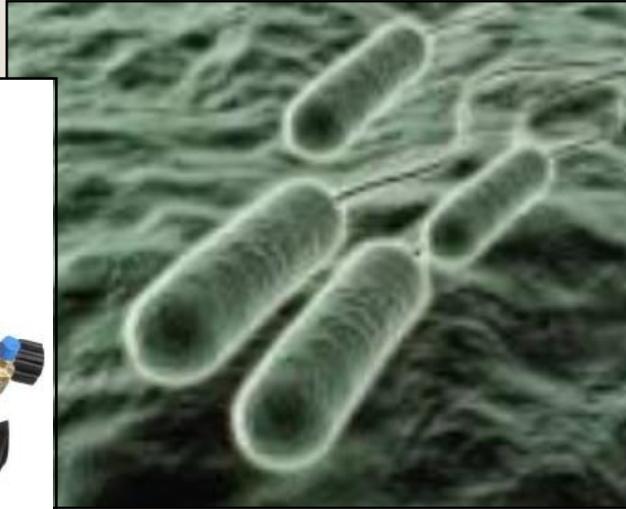
Short circuit





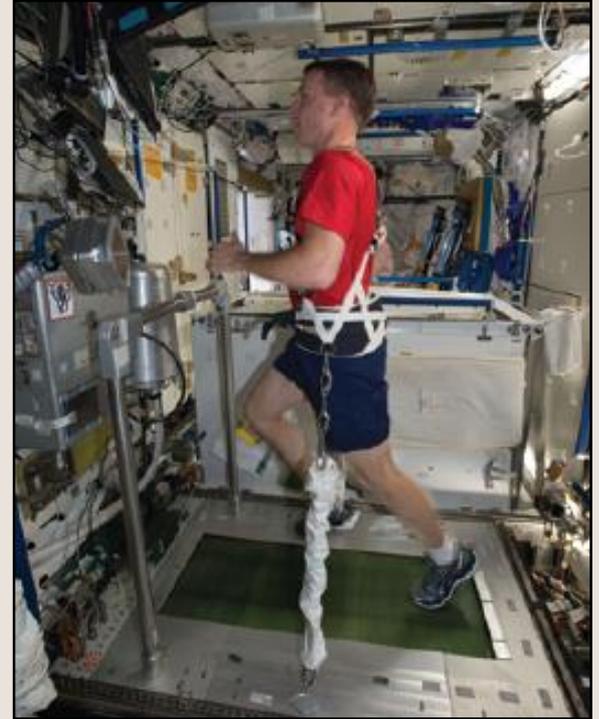
Breathable atmosphere

Bacteria and germs can grow more easy in enclosed environment





Keeping fit





Recovery of valuable supplies

What is important to recover/remove for both systems, some examples given below:

Breathing gas; oxygen – helium – nitrogen

Fluids; moisture – toilet usage – condensation

Unwanted matter; bacteria – dirt – food spills

Environment; heat – cold – contamination



Subsea and Space ; Best of both worlds !





Information and images

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We keep you breathing



The technology innovator.