Spaceflight Associated Neuro-ocular Syndrome (SANS)

A Briefing for Astronaut Candidates

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Space and Occupational Medicine Branch (SD3)

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Recent Headlines

Too much space travel is hazardous for your eyeballs

Spaceflight Bad for Astronauts' Vision, Study Suggests

By SPACE.com Staff | March 13, 2012 12:00am ET

Spacemen on the way to Mars will have to wear swimming goggles to save their sight say NASA experts

Possible Mars Mission 'Showstopper': Vision Risks for Astronauts

By Mike Wall, Senior Writer | April 8, 2014 07:00am ET

The mysterious syndrome impairing astronauts' sight

Health & Science

Houston, We Have an Eye Problem

Wednesday, September 9, 2020

Under Pressure: Why Spaceflight Is So Hard on Astronauts' Eyes

By Mike Wall published January 30, 2017

Apr 30, 2021, 04:55pm EDT | 1,066 views

How An Astronaut's Eyes Are Damaged By A Year In Space

JV Chamary Contributor

Science

I cover science and technology in popular culture

Astronauts' eyes are at risk after too much time in space

Astronauts Returning to Earth With Vision Problems

Video Channels

POST ORIGINALS · July 8, 2016

The Washington Post

Space travel is causing visual impairment for some astronauts. Will this prevent travel to Mars?

tended spaceflight is bad for astronauts' is building that it may cause vision

NASA's new sleeping bags could prevent eyeball 'squashing' on the ISS

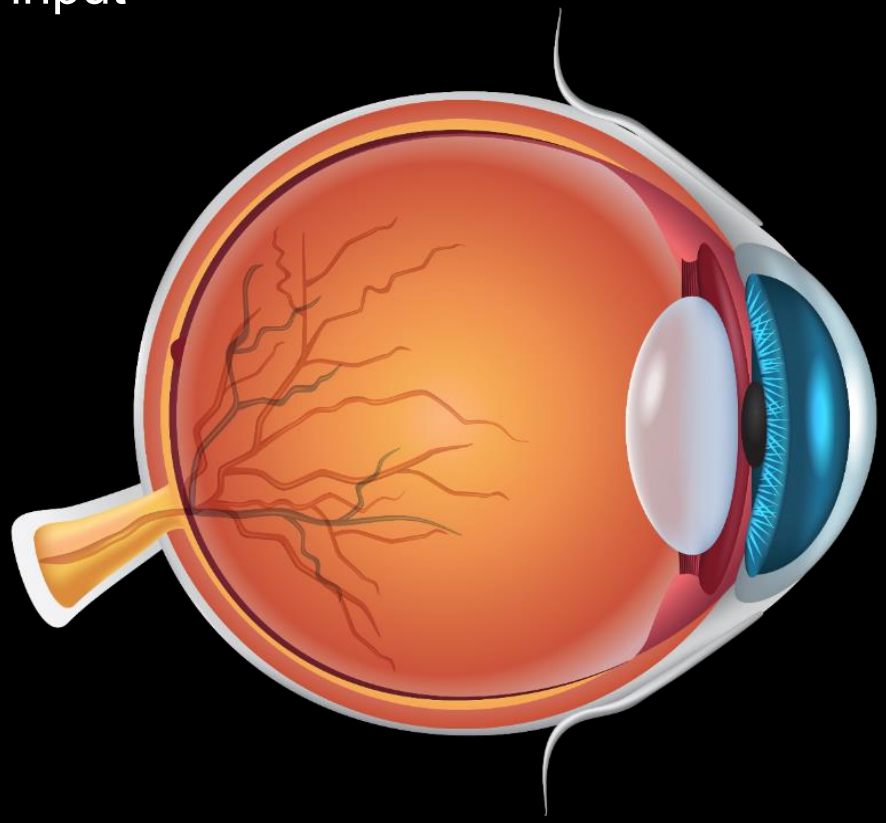
It sucks fluid out of astronaut's heads and toward their feet.

What's So Special About the Eye?

Image credit: NASA

What's So Special About the Eye?

- Only 1" in diameter, but provides ~80% of our total sensory input
- Retina and optic disc (aka optic nerve head)…
  - Convert light energy into neural signals, transmit information to brain via optic nerve fibers → "vision"
  - Extremely high metabolism, requires reliable & sustained blood supply
  - Affected by spaceflight in most crewmembers (SANS)
  - Central nervous system (CNS)
    - Susceptible to *permanent loss*



https://similarpng.com/eye-anatomy-details-clipart-png-2/

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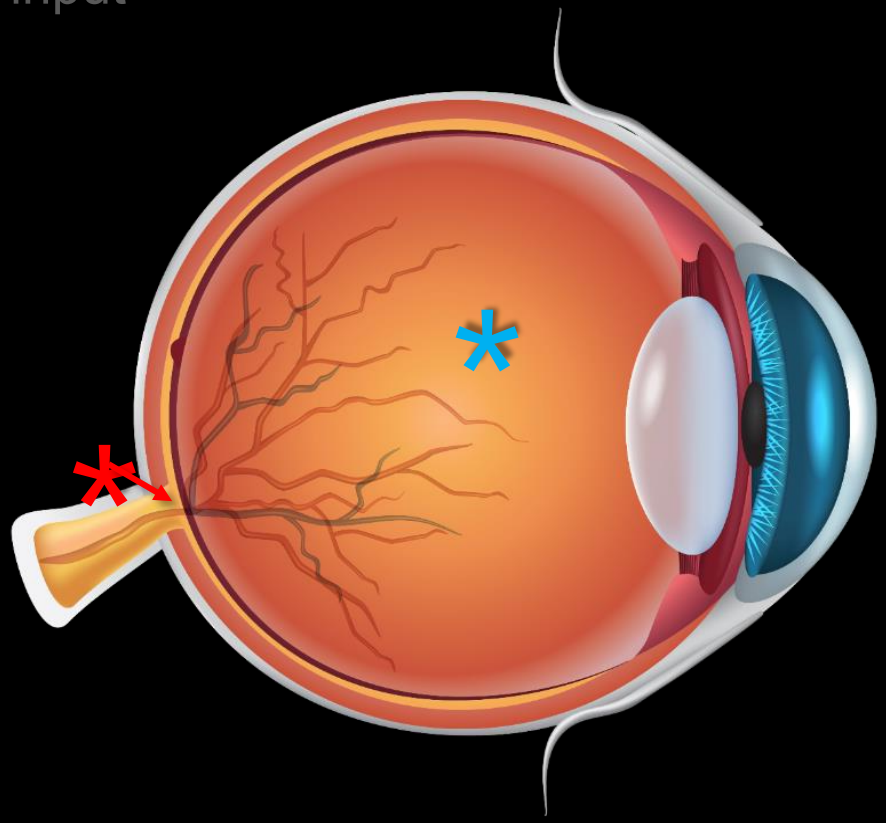

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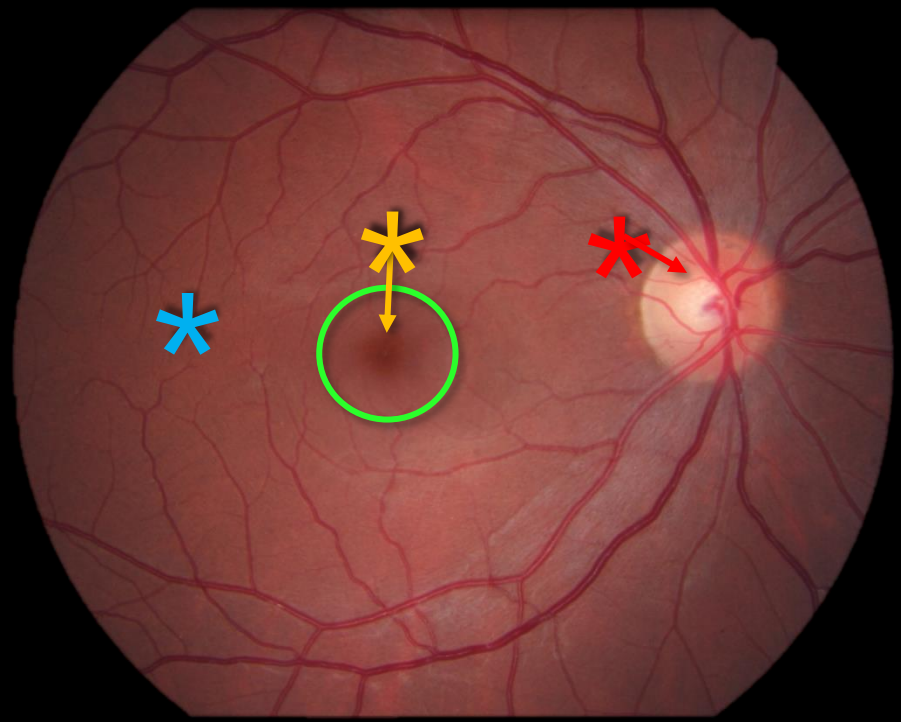
    - Susceptible to *permanent loss*
  - Includes retina's area of central vision: fovea & macula

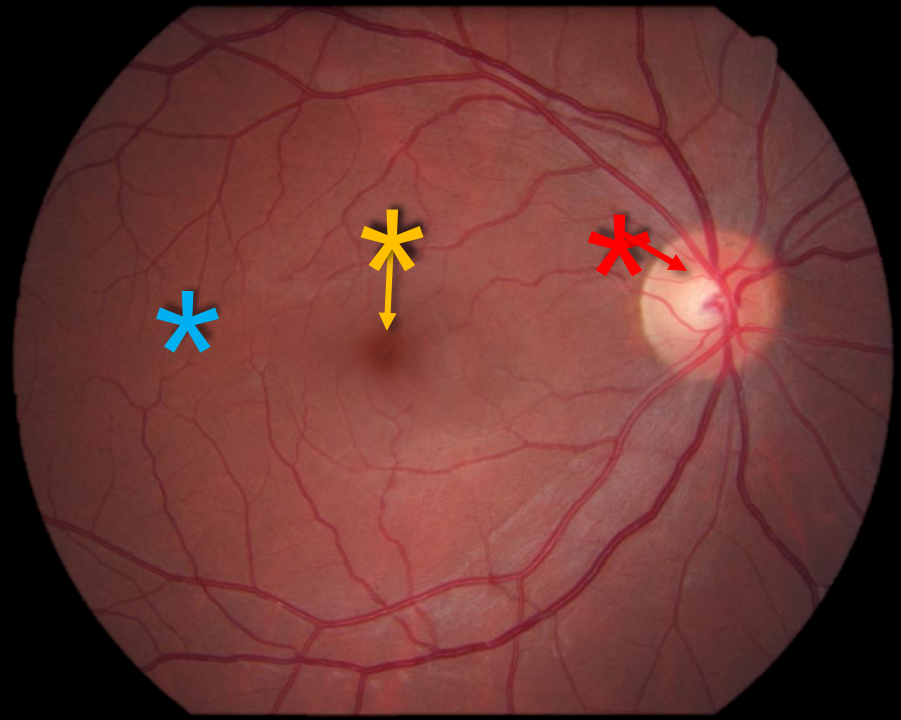


What's So Special About the Eye?

Optical coherence tomography (OCT)

- Our most critical tool to detect & monitor SANS
- Onboard ISS since 2013
- Provides non-invasive, high resolution, cross-sectional images

Image credit: NASA



Retina Optic disc Fovea

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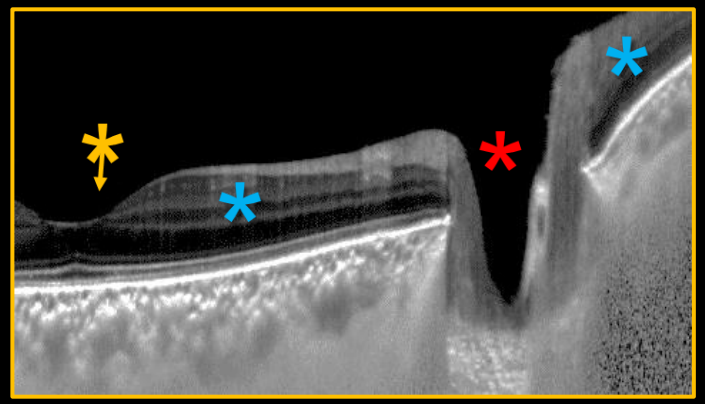
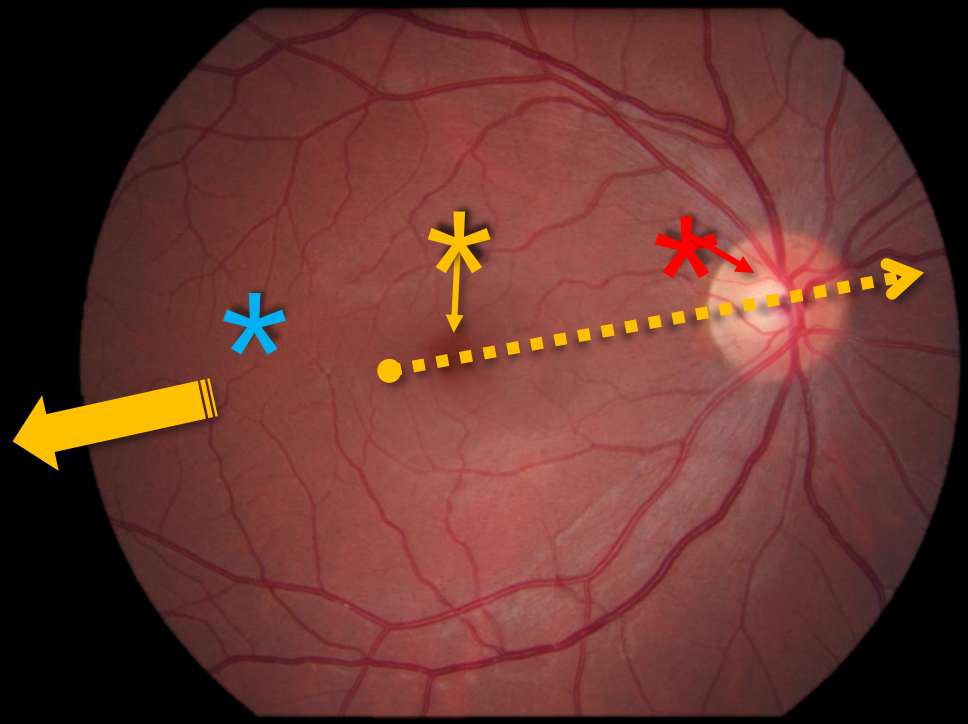




Retina Optic disc Fovea

Spaceflight Associated Neuro-ocular Syndrome (SANS)

Image credit: NASA

SANS Signs: *The Big Four*

Globe flattening

Refractive error shift

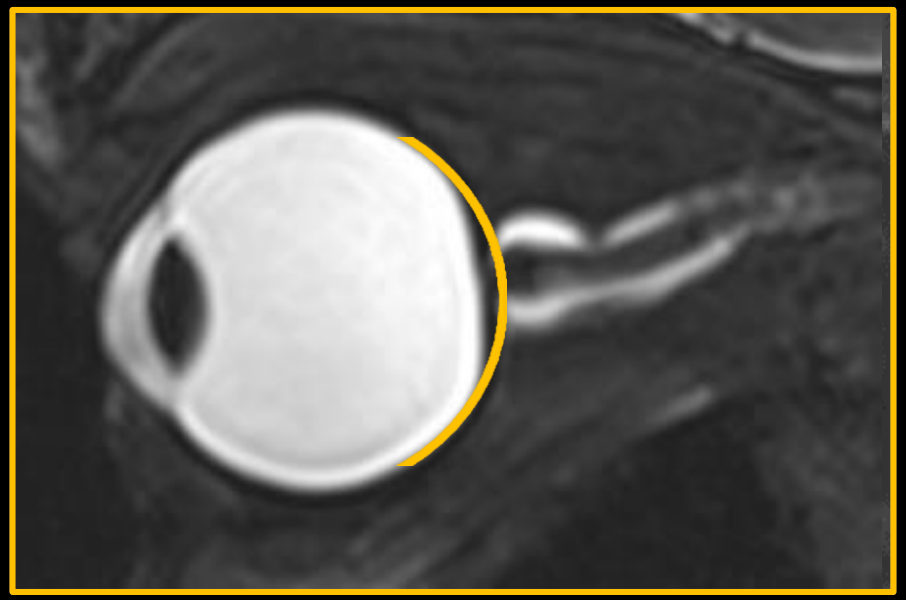
Optic disc edema

Chorioretinal folds

SANS Signs: *The Big Four*

Globe flattening | Refractive error shift | Optic disc edema | Chorioretinal folds

- Mild-to-severe cases: 23% of ISS crewmembers
- Risk: May change refractive error (power of glasses), but otherwise, no known risks
- Can become permanent (moderate-to-severe cases)



SANS Signs: *The Big Four*

Globe flattening | **Refractive error shift** | Optic disc edema | Chorioretinal folds

- "Hyperopic shift" (likely driven by globe flattening)
  - ≥ +0.75 diopter (D) shift: 15% of ISS crewmembers
  - Largest single-mission shift: +2.00D
- Risk: May blur near vision* (and/or distance vision)
  - In near-sighted (myopic) crew, may *improve* distance vision!
  - Bottom-line: *Report vision changes to your crew surgeons*
- Countermeasure: "Space anticipation glasses" (SAGs)
  - SAGs: Extra glasses supplied for mission, each w/ increasing power
  - *If vision degrades, select SAG that clears vision*
  - With proper correction, vision remains 20/20 or better
- Can become permanent (moderate-to-severe cases)

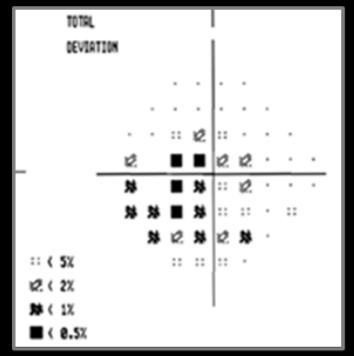
*

https://en.excimerclinic.ru/babyvision/longsight/

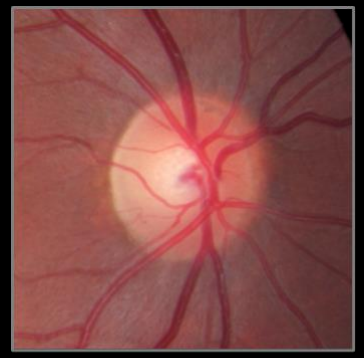
SANS Signs: *The Big Four*

Globe flattening | Refractive error shift | **Optic disc edema** | Chorioretinal folds

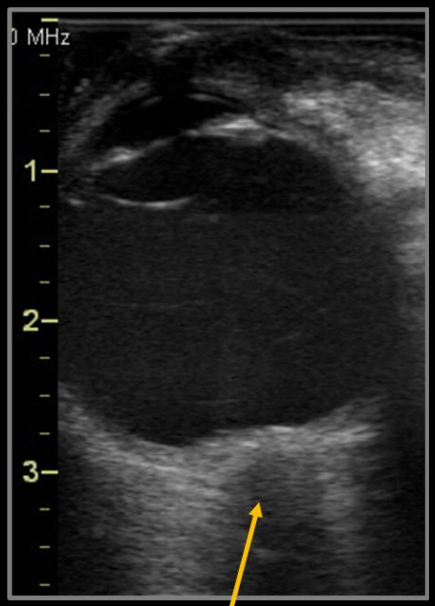
- Swelling of optic nerve head (CNS)
- Mild-to-severe cases: 66% of ISS crewmembers
- Risk: Visual field loss (enlarged blind spots)
  - Detected in 3% of ISS crew, immediately post-flight – Resolved
  - With extended duration and/or severity, *has potential* to become permanent
- Typically resolves ~3-12 months after return to 1G



Visual field defect, post-flight


Normal optic disc


SANS optic disc edema

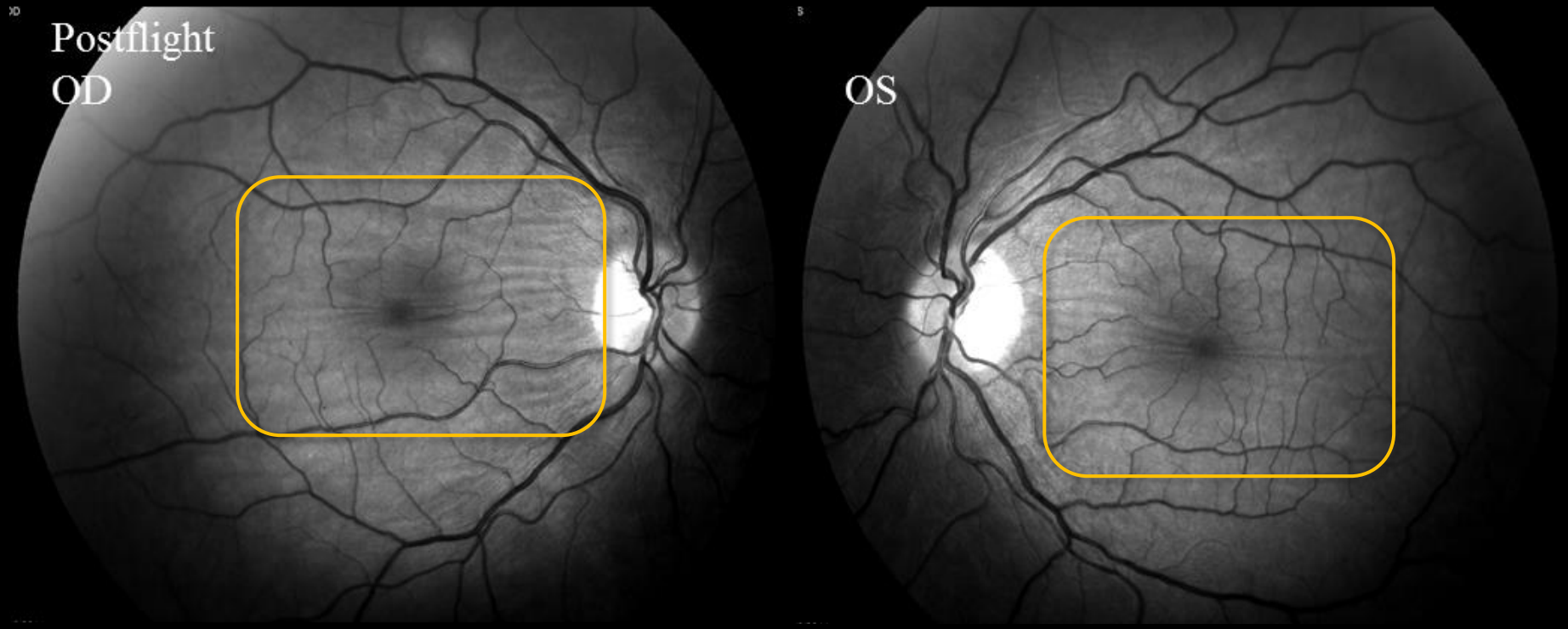


Elevated optic disc

SANS Signs: *The Big Four*

Globe flattening | Refractive error shift | Optic disc edema | **Chorioretinal folds**

- Folds within & below retina (CNS)



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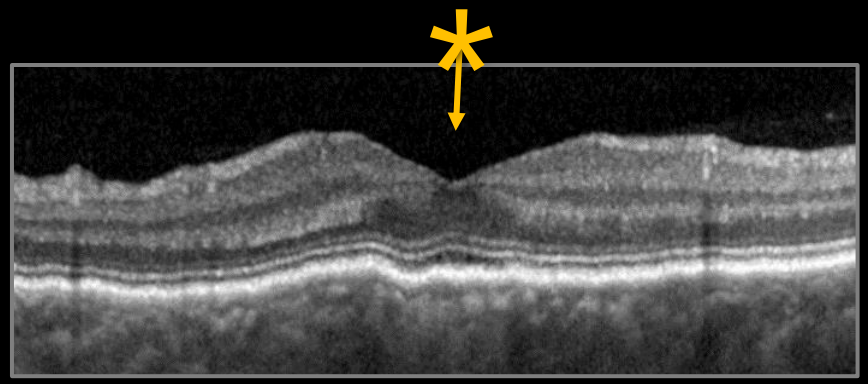
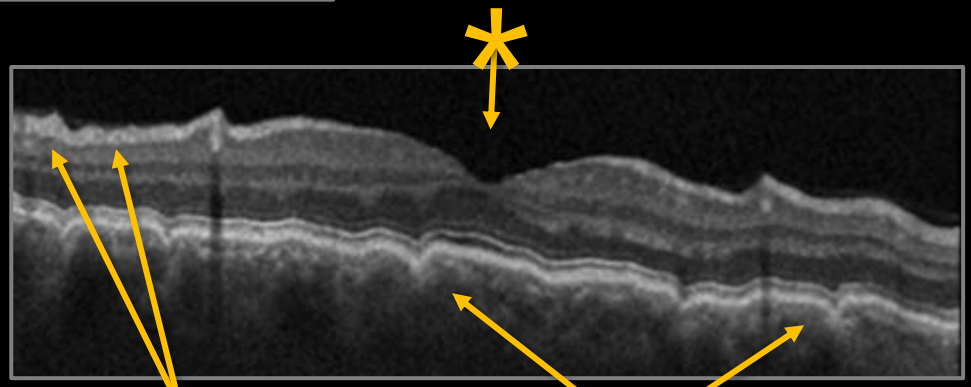




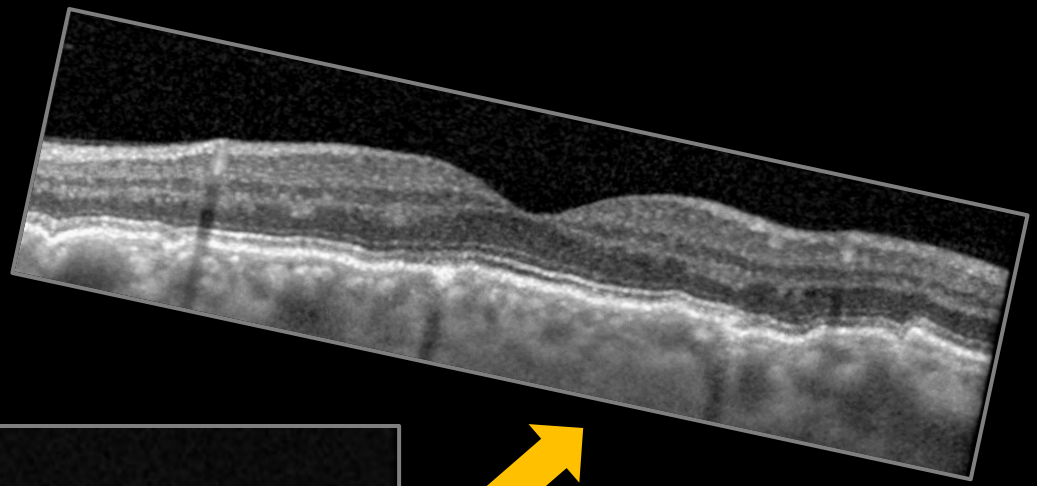
*Fovea

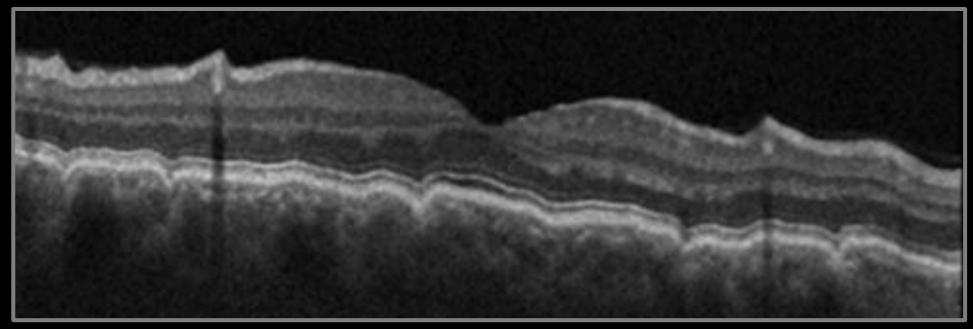
Image credit: NASA

SANS Signs: *The Big Four*

Globe flattening | Refractive error shift | Optic disc edema | **Chorioretinal folds**

- Folds within & below retina (CNS)
- Mild-to-severe cases: 16% of ISS crewmembers
  - Folds in fovea: 5% of ISS crewmembers
- Can become permanent (moderate-to-severe cases)





R+1/3d

R+>5y

Image credit: NASA

SANS Signs: *The Big Four*

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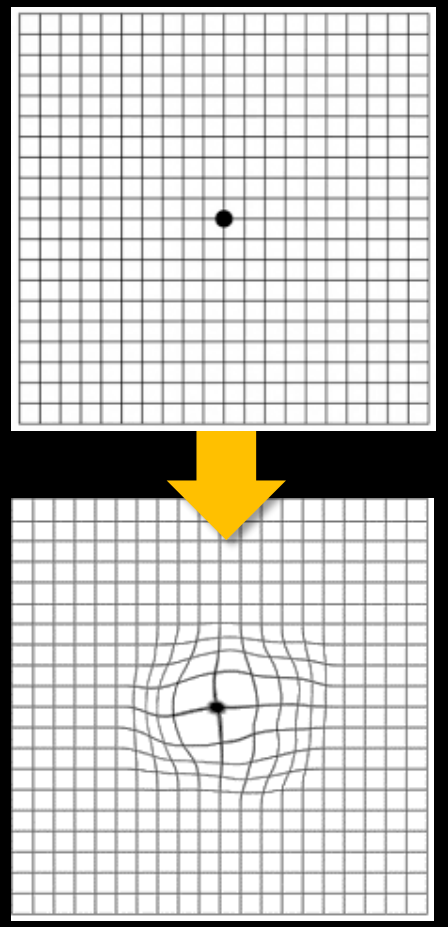
- Folds within & below retina (CNS)
- Mild-to-severe cases: 16% of ISS crewmembers
  - Folds in fovea: 5% of ISS crewmembers
- Can become permanent (moderate-to-severe cases)
- Risk: Distorted central vision, if severe folds located in macula/fovea
  - Detected in 0% of ISS crew
  - With increased duration and/or severity, *has potential* to become permanent, cause retinal damage



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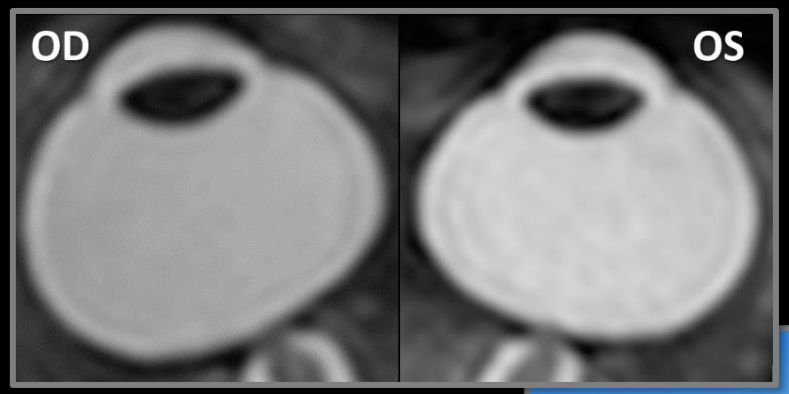

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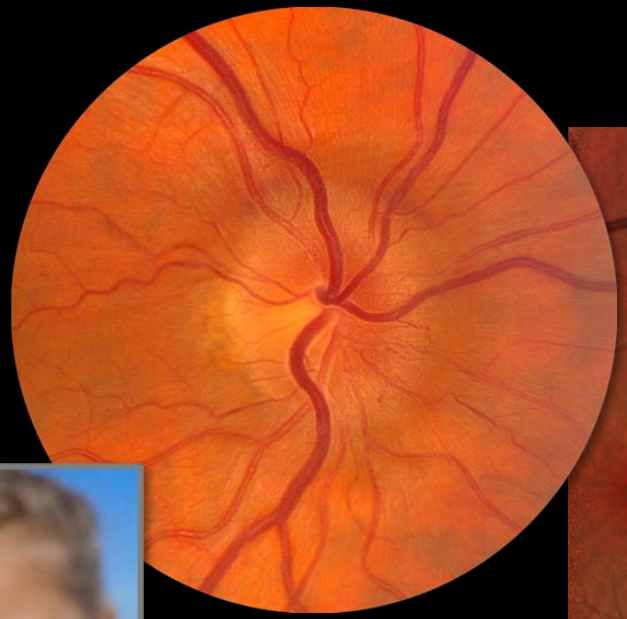
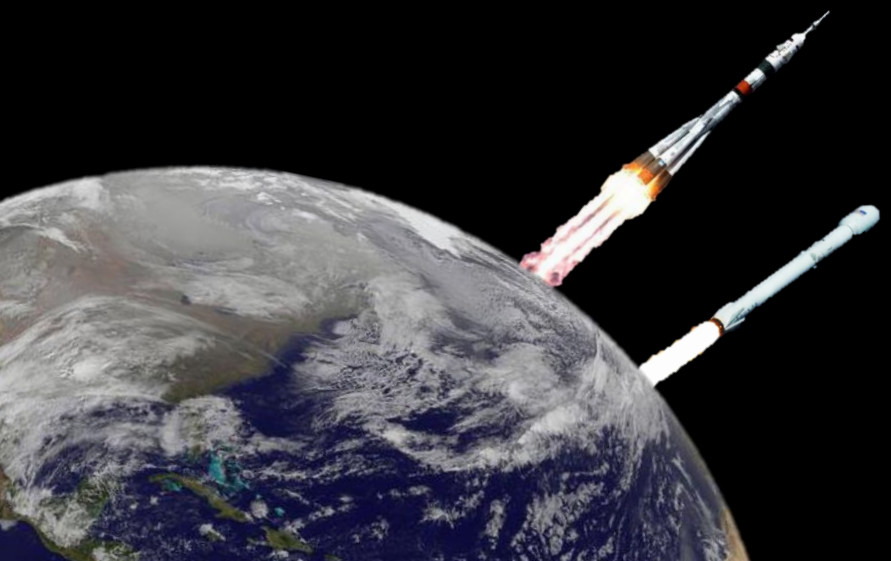


What *in the world* is going on?

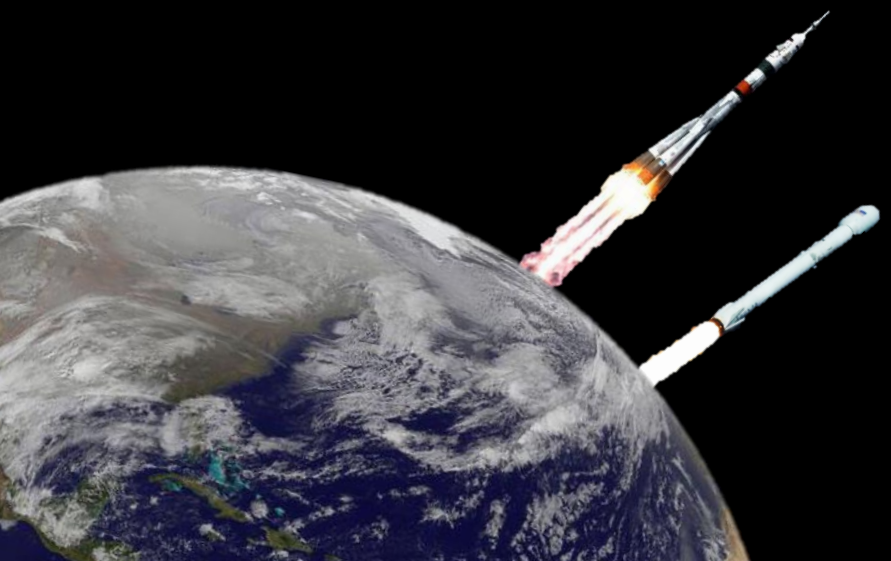
Mission Duration: *Long* (~6-12 mo)

Micro-gravity



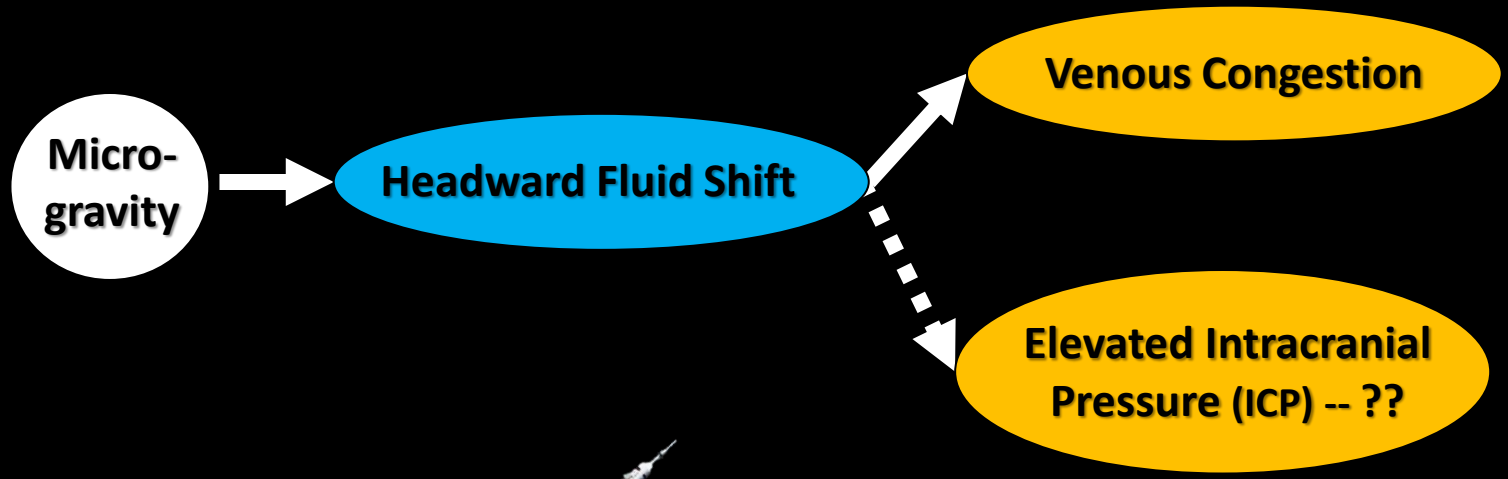
Mission Duration: *Long* (~6-12 mo)

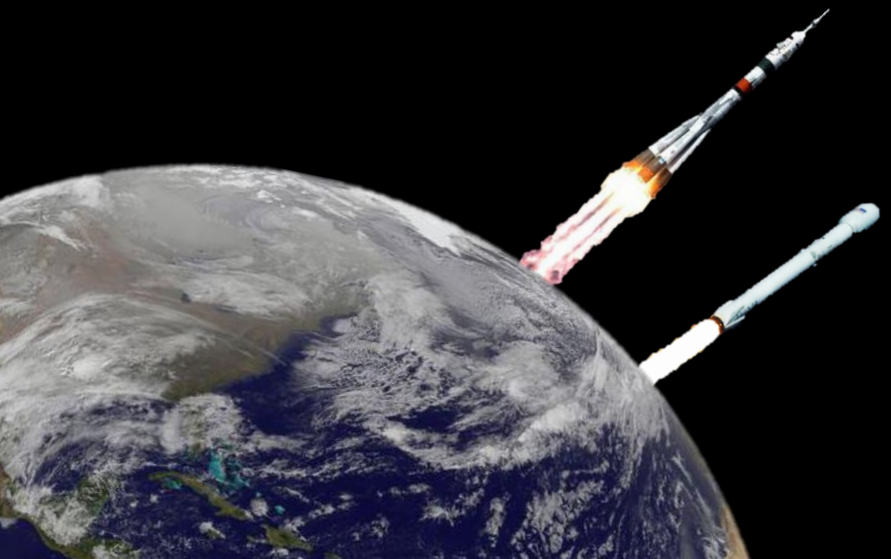
Micro-gravity → Headward Fluid Shift



"Puffy Face Syndrome"

Mission Duration: *Long* (~6-12 mo)





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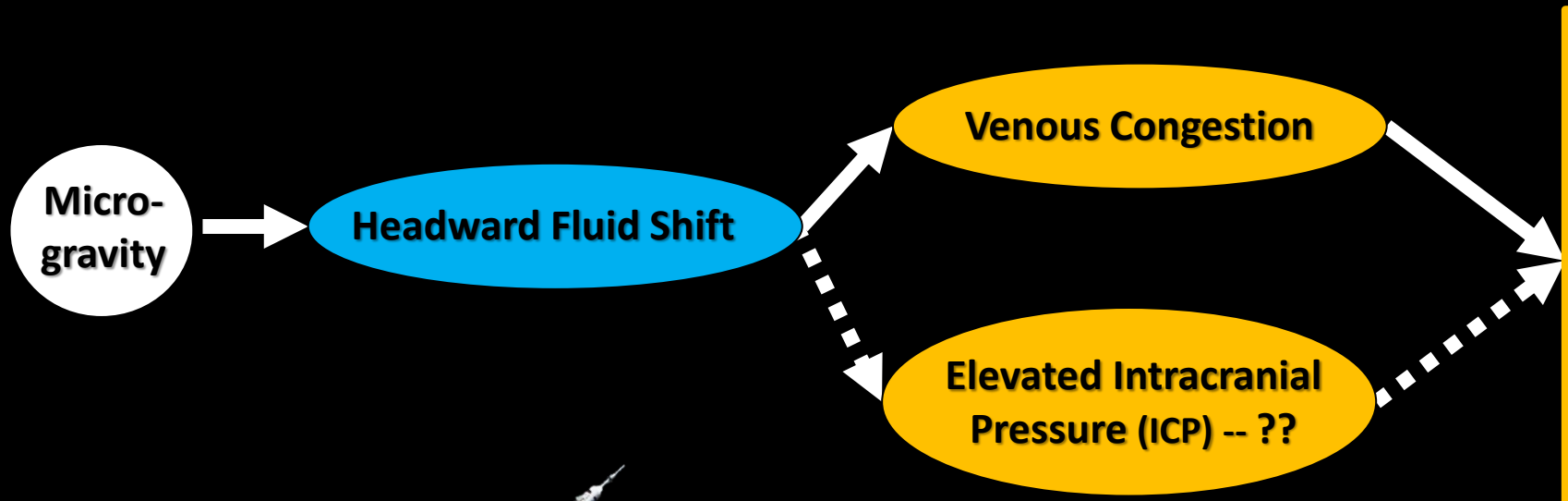
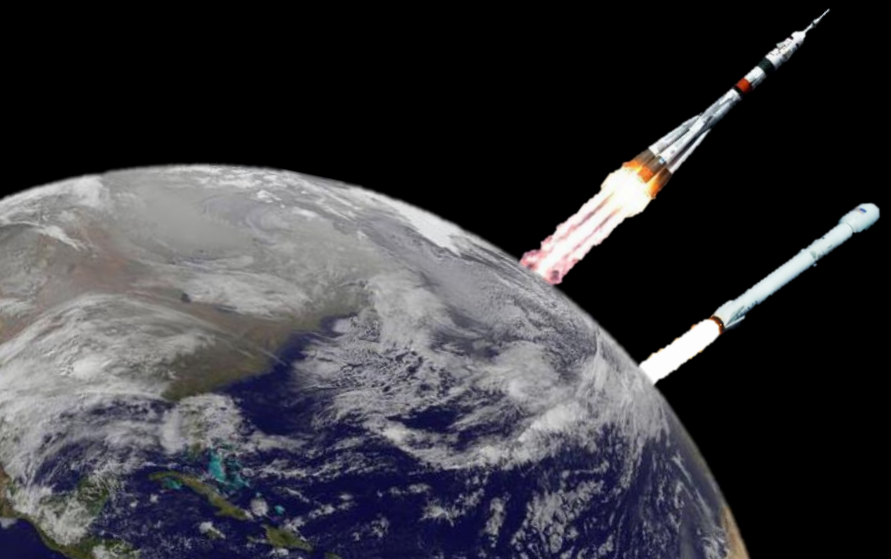




Optic Disc Edema, Globe Flattening, Choroidal Folds, and Hyperopic Shifts Observed in Astronauts after Long-duration Space Flight

Thomas H. Mader, MD,[1] C. Robert Gibson, OD,[2] Anastas F. Pass, OD, JD,[3] Larry A. Kramer, MD,[4] Andrew G. Lee, MD,[5] Jennifer Fogarty, PhD,[6] William J. Tarver, MD,[6] Joseph P. Dervay, MD,[6] Douglas R. Hamilton, MD, PhD,[7] Ashot Sargsyan, MD,[7] John L. Phillips, PhD,[8] Duc Tran, DO,[2] William Lipsky, MD,[2] Jung Choi, OD,[2] Claudia Stern, MD, PhD,[9] Raffi Kuyumjian, MD,[10] James D. Polk, DO[6]

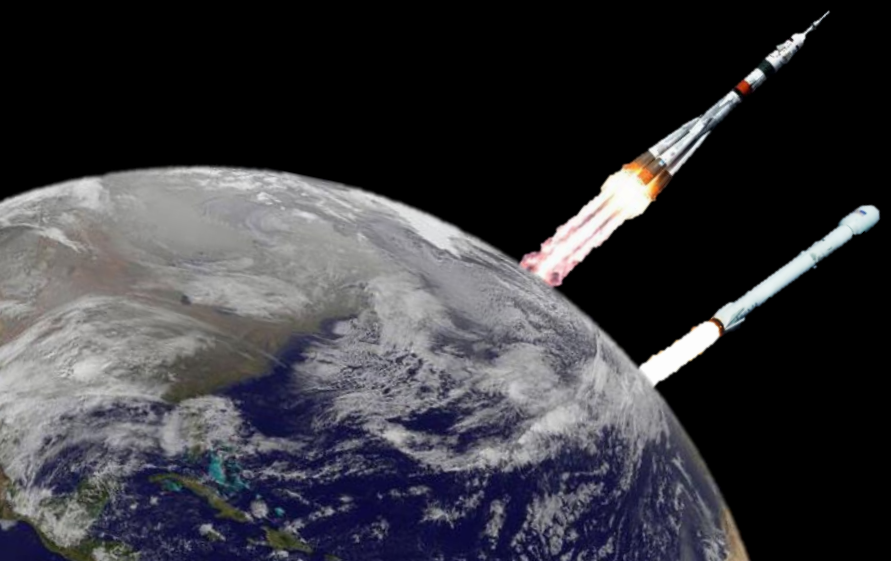
Ophthalmology 2011;118:2058–2069

Mission Duration: *Long* (~6-12 mo)

Micro-gravity → Headward Fluid Shift → Venous Congestion / Elevated Intracranial Pressure (ICP) -- ??

Optic Disc Edema
Chorioretinal Folds
Globe Flattening
Hyperopic Shifts

Decreased Near VA
57% (Self-reported)



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Micro-gravity

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Venous Congestion

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Optic Disc Edema
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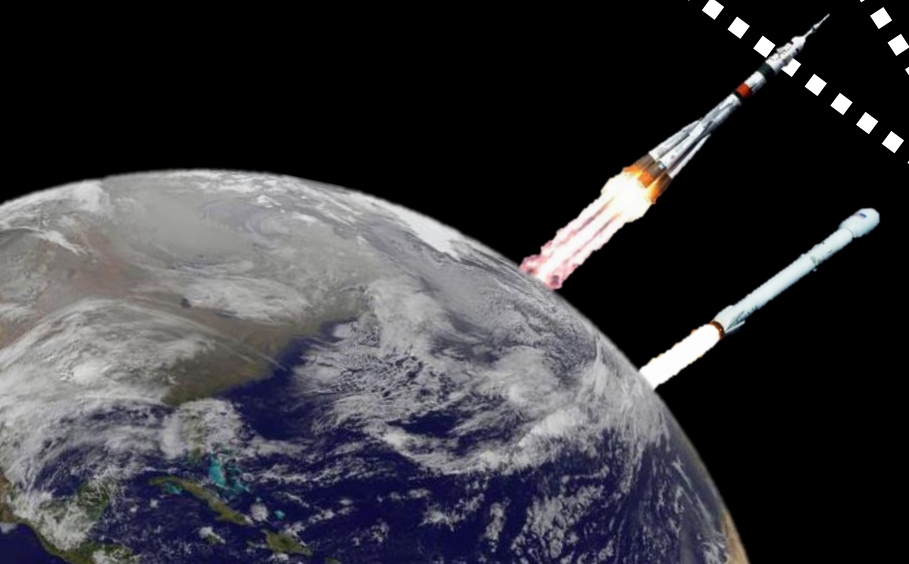
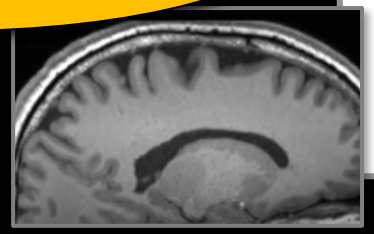
Brain displaces upward & lateral ventricles enlarge





The NEW ENGLAND JOURNAL of MEDICINE

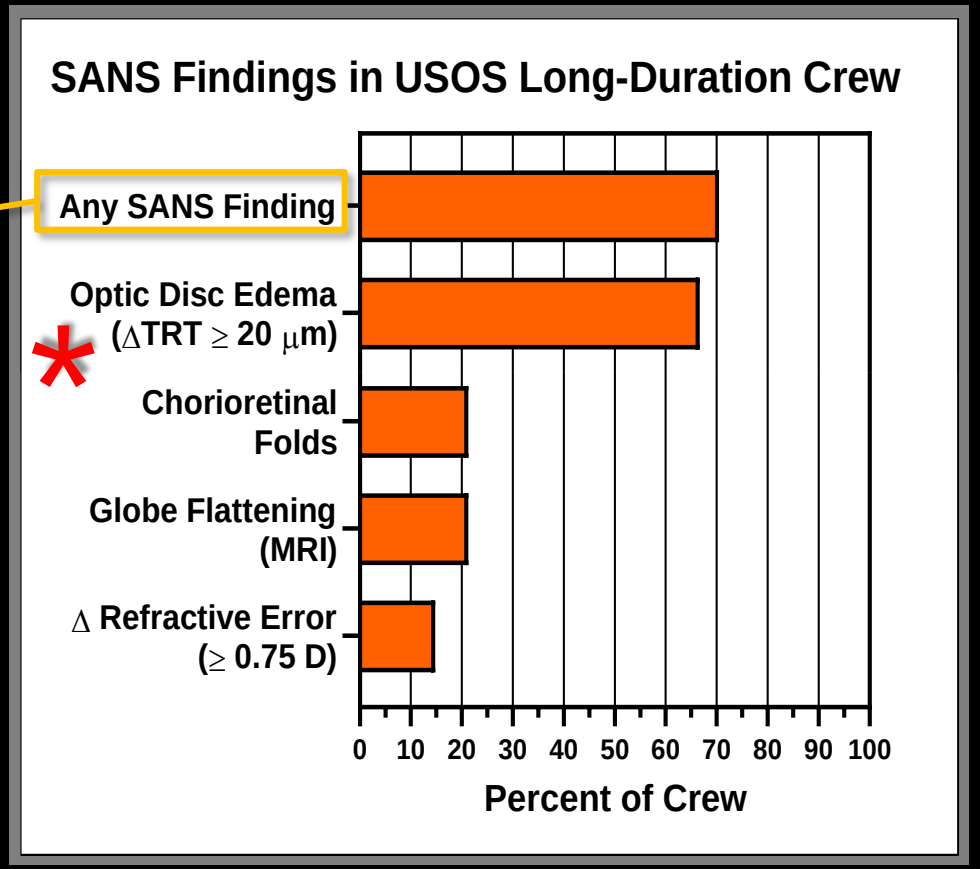
ORIGINAL ARTICLE

Effects of Spaceflight on Astronaut Brain Structure as Indicated on MRI

Donna R. Roberts, M.D., Moritz H. Albrecht, M.D., Heather R. Collins, Ph.D., Davud Asemani, Ph.D., A. Rano Chatterjee, M.D., M. Vittoria Spampinato, M.D., Xun Zhu, Ph.D., Marc I. Chimowitz, M.B., Ch.B., and Michael U. Antonucci, M.D.

Mission Duration: *Long* (~6-12 mo)

- No permanent loss of vision or cognitive function yet detected in any crew
- About 70% of long-duration crewmembers present w/ signs of SANS (from mild to severe)
  - Diagnosed in males *and* females, in novice & veteran crewmembers, in either/both eyes
  - *Can't yet predict* who will develop SANS
- Severity *related to mission duration*
- Some changes can become *permanent* (i.e., globe flattening, hyperopic shifts, choroidal folds)



Data courtesy of NASA LSAH

* **ΔTRT = Change in total retinal thickness** near optic disc (vs. pre-flight). Objectively quantifies optic disc edema

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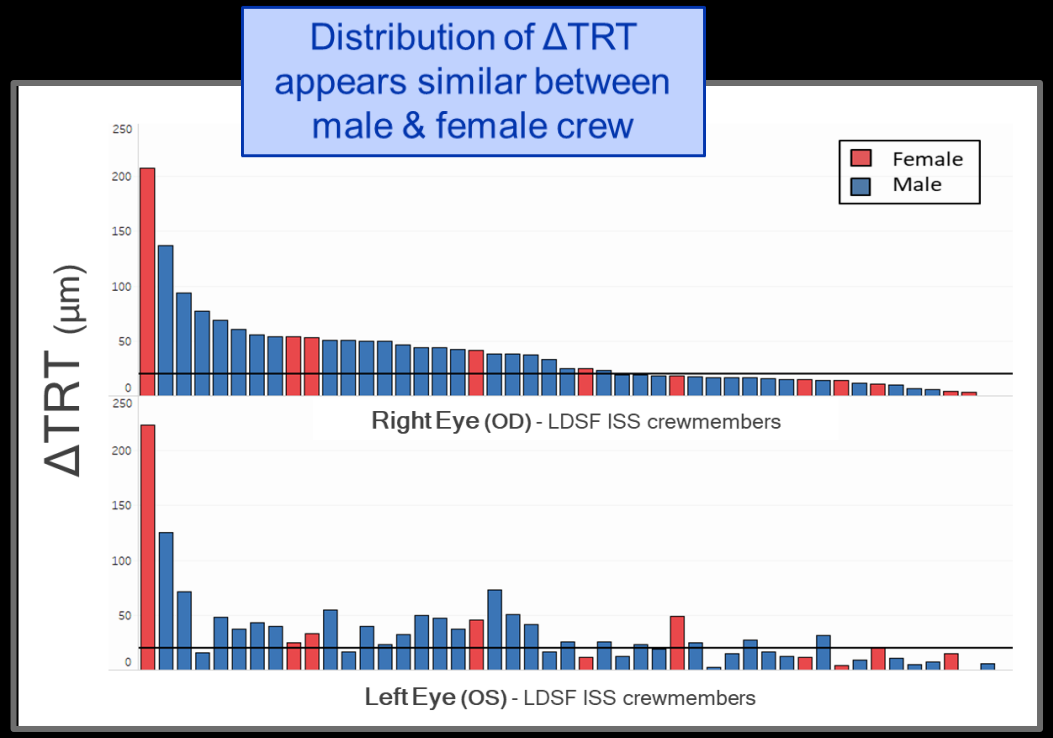

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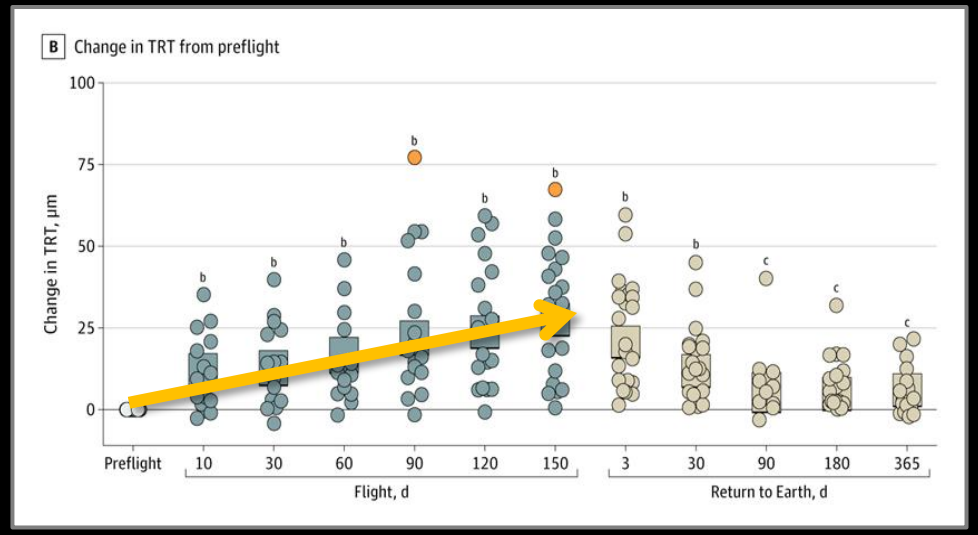

Macias BR, et al. Association of long-duration spaceflight with anterior and posterior ocular structure changes in astronauts and their recovery. JAMA Ophthalmol. 2020 Apr 02

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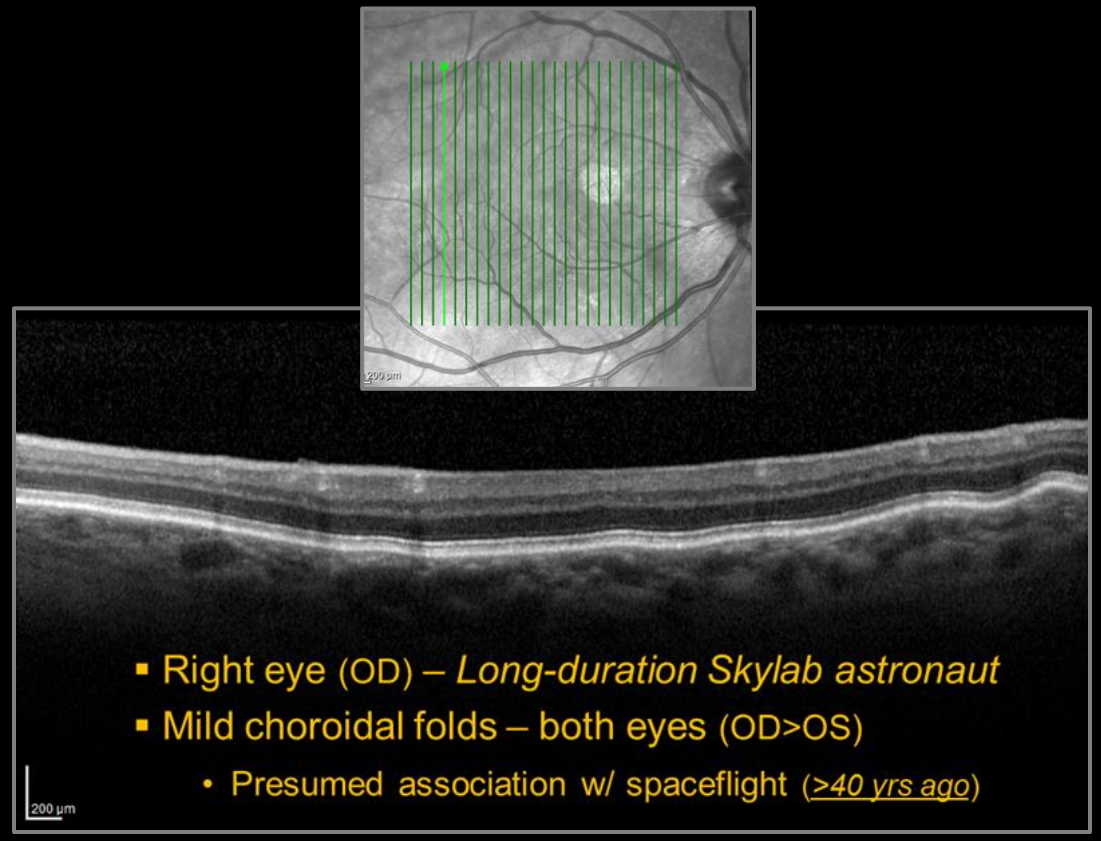
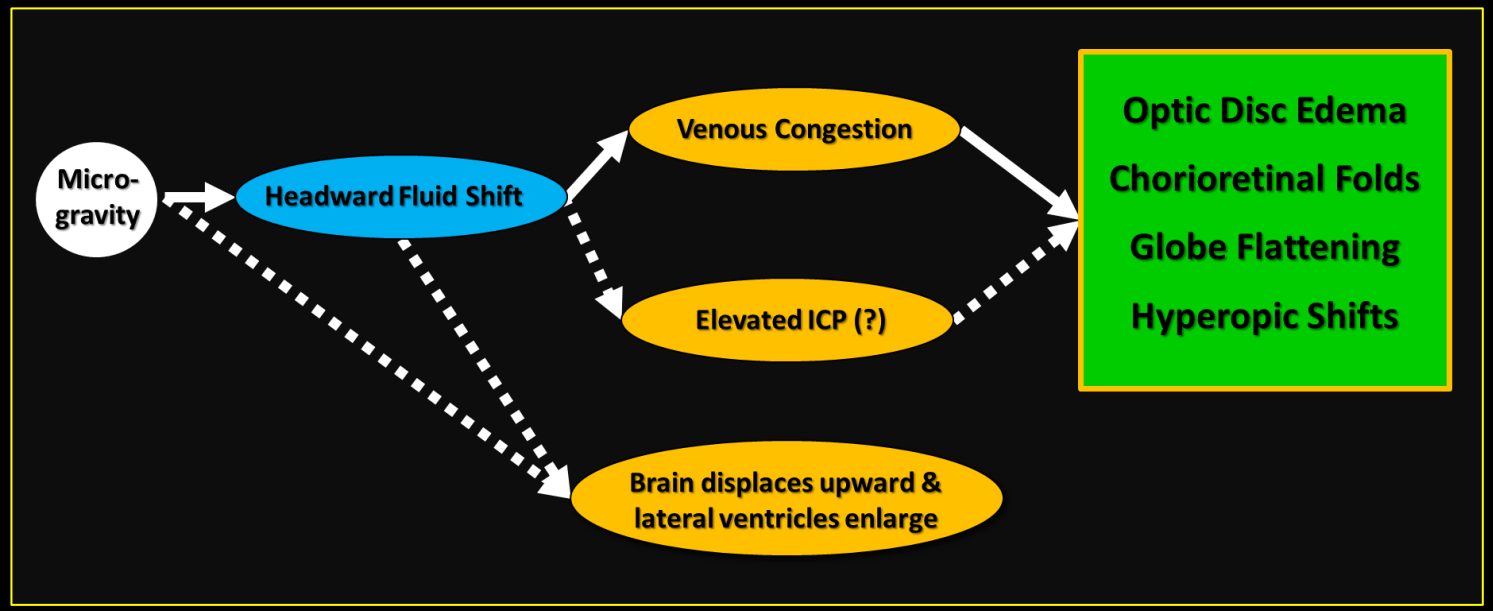
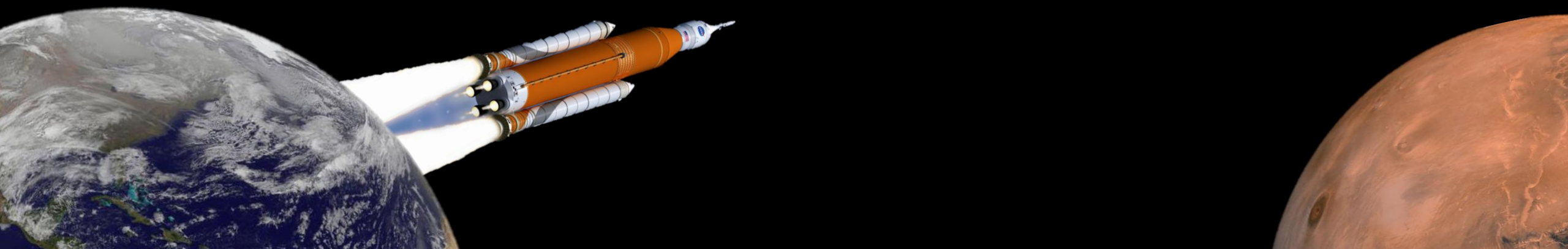
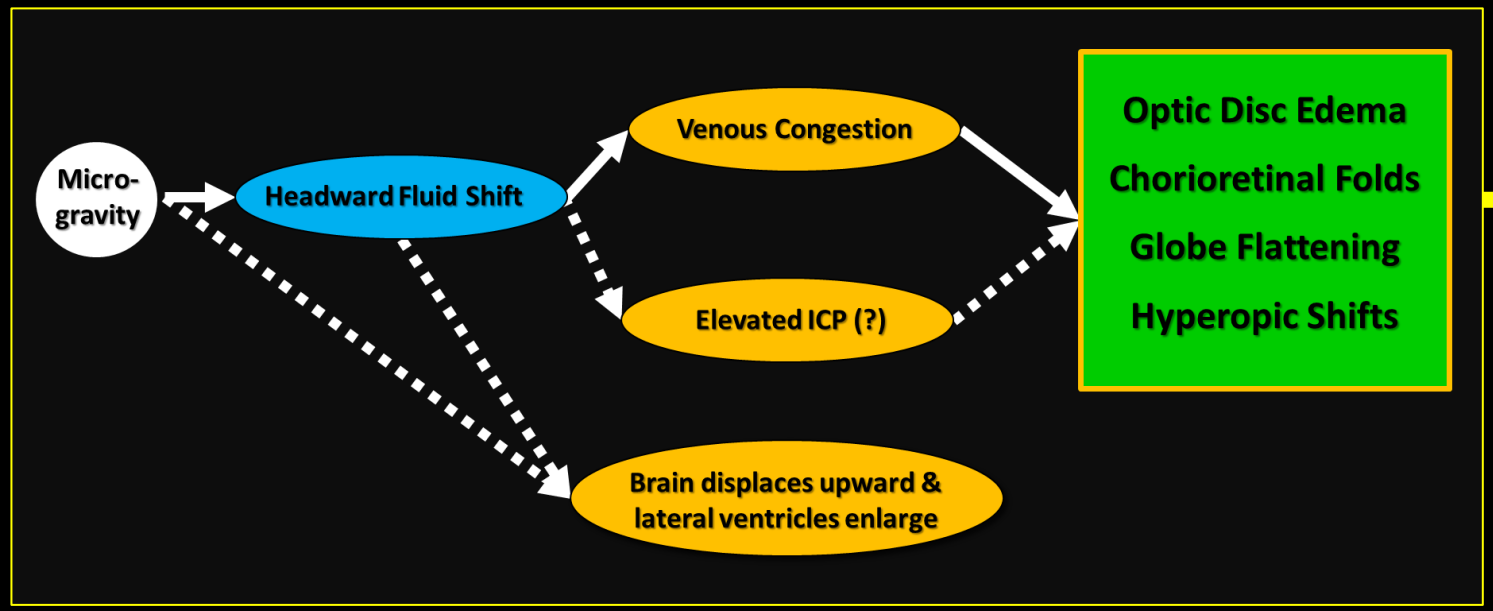


Mission Duration: *Exploration* (~2–3 years)





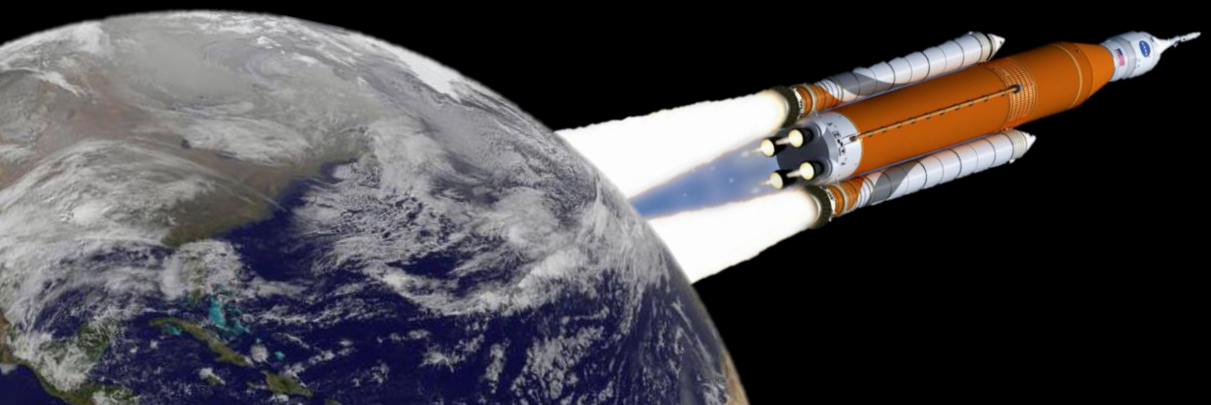
Mission Duration: *Exploration* (~2–3 years)



↑ Duration may lead to ↑ Severity

↑ risk for in-flight & long-term health consequences

- Permanent VF defects?
- Visual distortions?
- Unexpectedly large refractive error shifts?

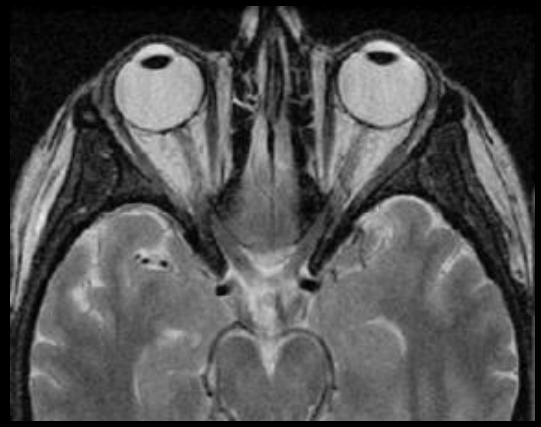


Medical Testing & Surveillance

Image credit: NASA

Medical Testing & Surveillance

Primary SANS/Ocular Tests	Pre-flight	On-orbit			Post-flight
		FD30	FD90	R-30	
3T MRI – *Head & Orbits*	X	--	--	--	X
Comprehensive Eye Exam	X	--	--	--	X
Visual Field	X	Not yet on-orbit			X
Vision Screening – *VA, Amsler grid, Survey*	X	X	X	X	X
Retinal Photography – *"Fundoscopy"*	X	X	X	X	X
Optical Coherence Tomography	X	X	X	X	X
Ocular Ultrasound	X	X	X	X	X
Tonometry – *Intraocular Pressure*	X	X	X	X	X
		Note: ESA only; ACI otherwise			



https://www.ophthalmicmart.com/product/humphrey-field-analyzer-3/

Medical Testing & Surveillance

Primary SANS/Ocular Tests	Pre-flight	On-orbit			Post-flight
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Comprehensive Eye Exam	X	--	--	--	X
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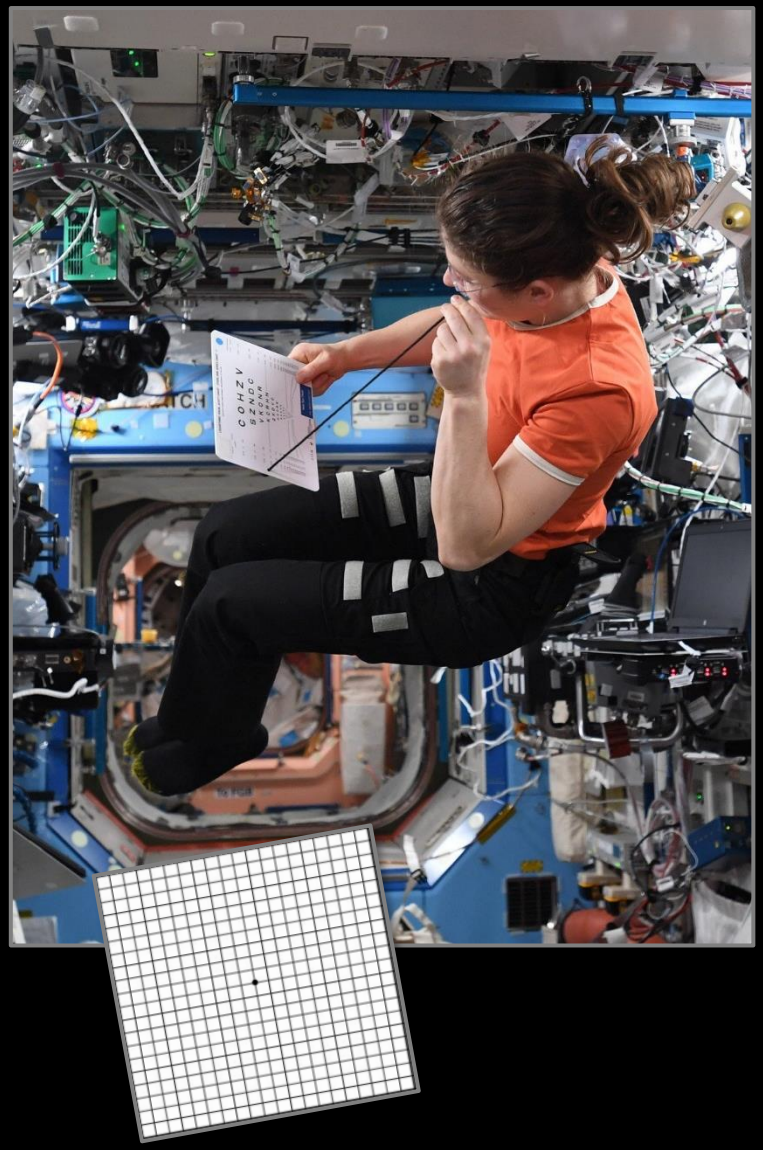

Image credit: NASA

Medical Testing & Surveillance

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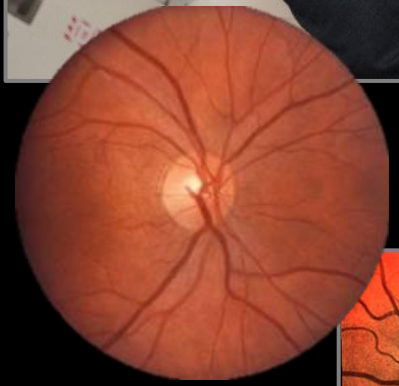
Image credit: NASA



Medical Testing & Surveillance

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Image credit: NASA

Medical Testing & Surveillance

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Image credit: NASA

Medical Testing & Surveillance

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		Note: ESA only; ACI otherwise			

Image credit: NASA

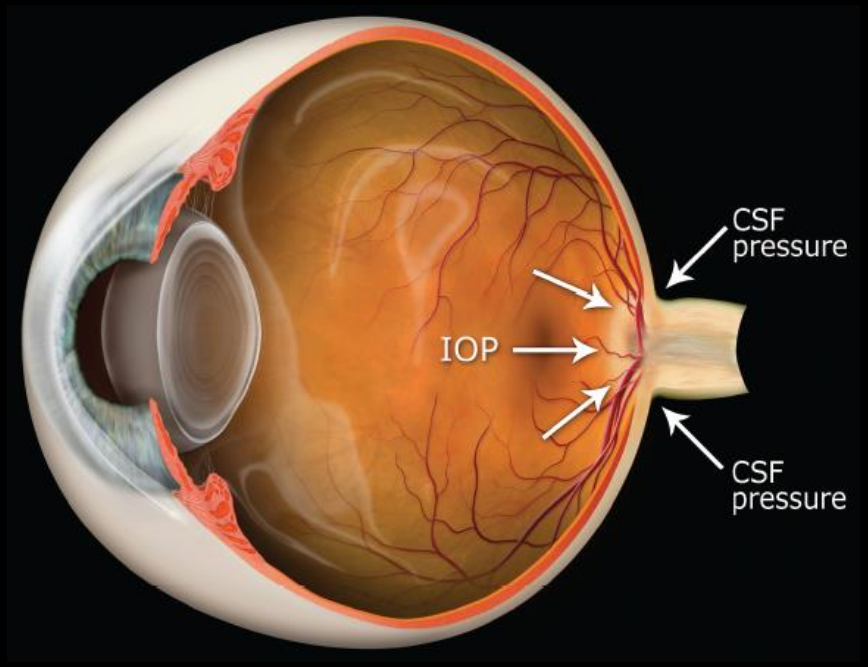
Why is this Happening?

Image credit: NASA

Why is this Happening?

Top SANS Pathogenesis Theories

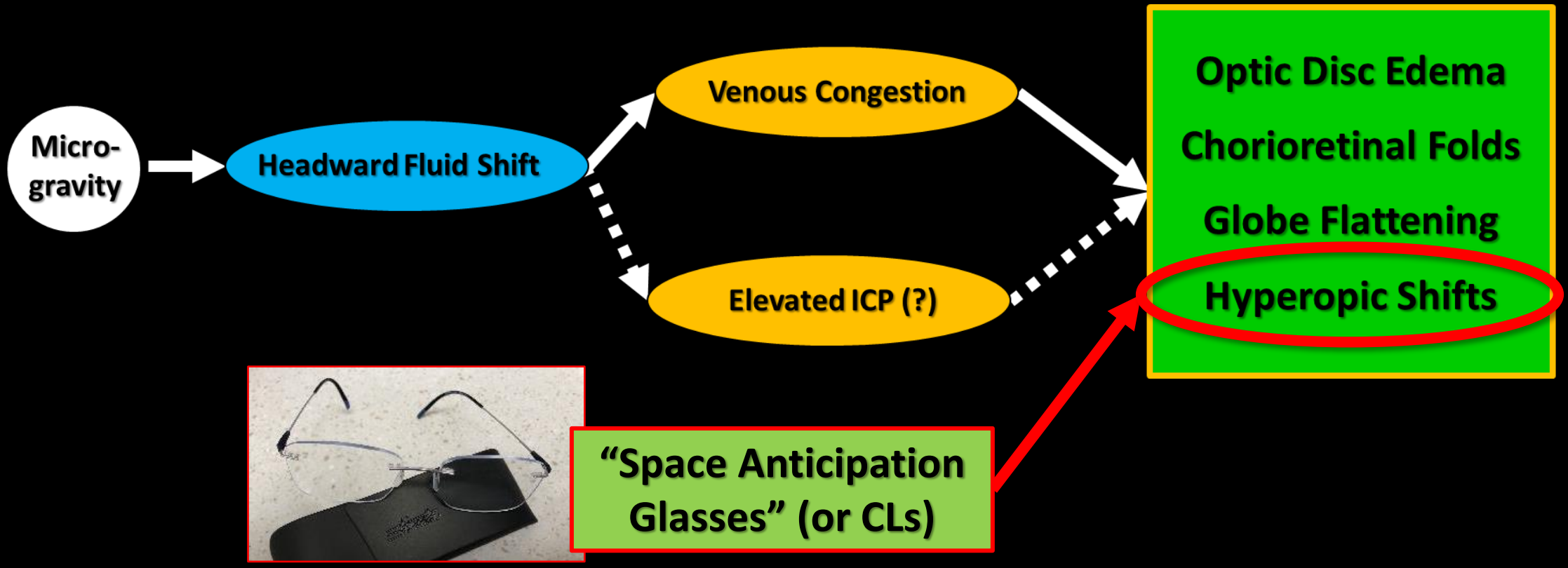
- Hypothesis #1: *Increased optic nerve sheath pressure*
  - Due to an overall increase in ICP or localized to the perioptic subarachnoid space (e.g., due to compartmentalization)
  - Enough to cause an imbalance between ICP & intraocular pressure (i.e., a translaminar pressure gradient)
- Hypothesis #2: *Venous congestion* alters local physiology, reduces blood profusion, and/or places direct pressure on retinal axons
- Hypothesis #3: *Individual anatomical/genetic factors*
  - e.g., Altered folate-dependent 1-carbon metabolism



Mitigation Strategies

Image credit: NASA

SANS Mitigation Strategies



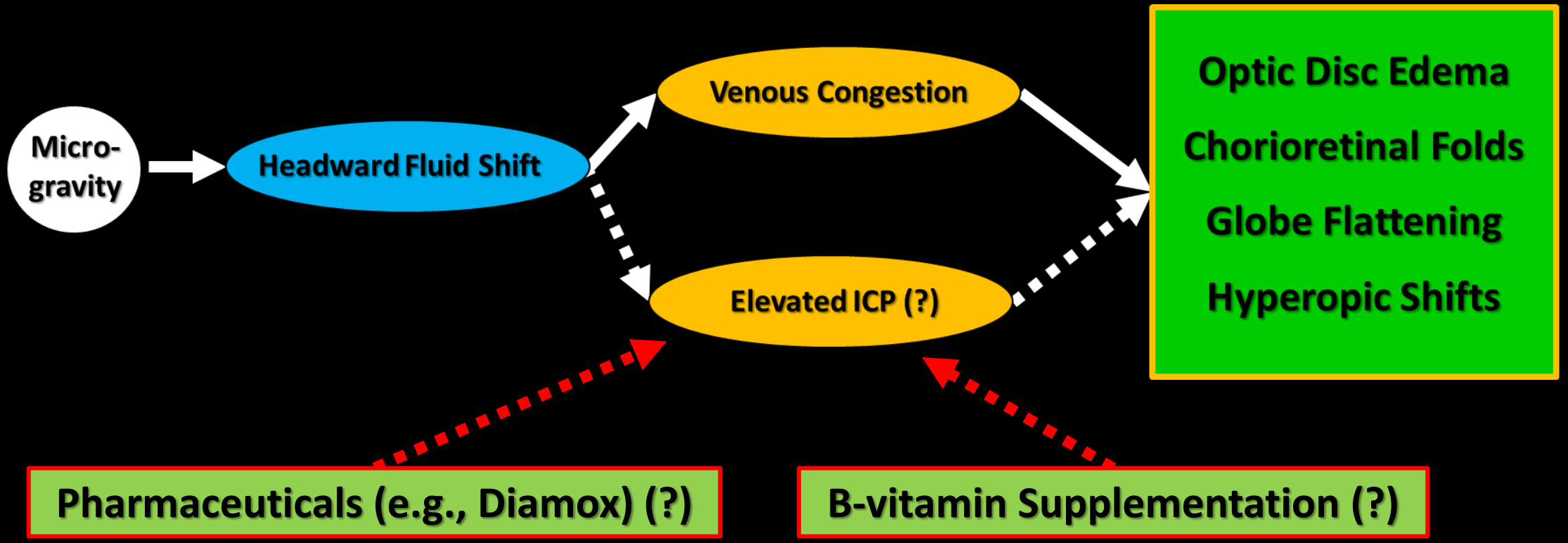
SANS Mitigation Strategies

- Artificial Gravity
- Lower Body Negative Pressure (?)
- Thigh Cuffs (?)

Micro-gravity → Headward Fluid Shift → Venous Congestion / Elevated ICP (?)

Venous Congestion / Elevated ICP (?) → Optic Disc Edema, Chorioretinal Folds, Globe Flattening, Hyperopic Shifts

SANS Mitigation Strategies

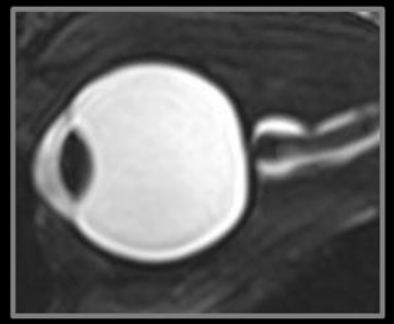
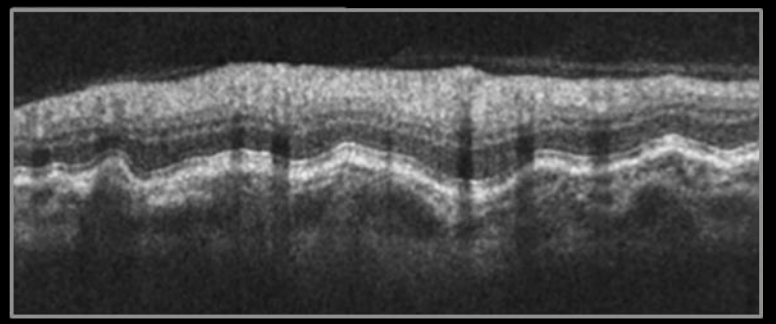
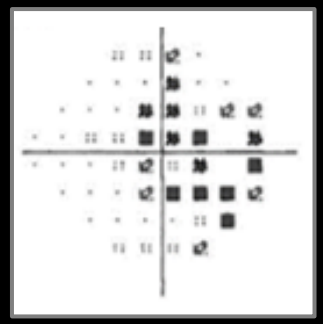


Bottom-line Messages: SANS

Image credit: NASA

Bottom-line Messages: SANS

- Currently, *no evidence* of cognitive impairment or permanent vision loss in *any* astronauts
- No mission has lost objectives secondary to SANS
- 70% of ISS crewmembers diagnosed w/ SANS, while *18% develop clinically-concerning SANS*
- Cases are typically *asymptomatic* unless they develop *blurred vision*
  - Inform your crew surgeons about any vision changes
- SANS countermeasures are being aggressively pursued & studied
  - Please consider volunteering for SANS research (e.g., ISAFE)
- SANS severity is related to mission duration. SANS poses a significant risk during extended-duration spaceflight (e.g., a >2-yr Mars mission)

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SANS Prevalence

Feature of SANS	DIAGNOSTIC THRESHOLDS FOR SANS							
	Earliest indication	***72%***	***Clinically Concerning***	***18%***	***Pathological: Acute Functional Impact***	***6%***	***Pathological: Affecting Long-Term Health***	***0%***
OPTIC DISC EDEMA	≥ +20 µm ΔTRT and/or evidence of mild edema not meeting Frisèn grade 1	66%	≥ +55 µm ΔTRT and/or Frisèn grade ≥ 1 Note: Post-flight lumbar puncture recommended	17%	Visual field loss (e.g., enlarged blindspot) *Associated anatomical signs to be determined*	3%	Permanent visual field loss and/or reduced retinal nerve fibre layer (RNFL) thickness	0%
CHORIORETINAL FOLDS	Any evidence of folds (i.e., choroidal, retinal or peripapillary wrinkles)	16%	Sharp folds in vicinity of macula	5%	Distorted central vision *Associated anatomical signs to be determined*	0%	Permanently distorted central vision, atrophy of retinal pigment epithelium (RPE) or photoreceptors, and/or choroidal neovascularization	0%
GLOBE FLATTENING	Any evidence of posterior globe flattening (centered at optic nerve) and/or decreased axial length (centered at fovea)	23%	Moderate change	12%	RE shift *beyond* power of available in-flight "Space Anticipation Glasses"	--	Currently unknown	--
REFRACTIVE ERROR (RE) SHIFT	≥ +0.75 diopters	15%	≥ +1.50 diopters (i.e., RE shift *approaching* power limit of available in-flight "Space Anticipation Glasses")	5%		2%	Currently unknown	--

Data courtesy of LSAH (Sara Mason)

Note: *Percentages rounded to whole numbers*

Questions?

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