UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION

AERONAUTICS and ASTRONAUTICS

Cubesats Missions of Turkey

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Outline

- Briefly University of Turkish Aeronautical Association
- Satellites of Turkey
- Cubesats of Turkey
- Cubesat plans of UTAA / Vision?

University of Turkish Aeronautical Association

- Turkish Aeronautical Association (1925)

- University of Turkish Aeronautical Association (2011)

University of Turkish Aeronautical Association

Satellite Counts in Orbit

	IN ORBIT				
COUNTRY	UNASSIGNED	PAYLOAD	ROCKET BODY	DEBRIS	TOTAL
ALL (ALL)	144	5017	2192	12296	19649
UNITED STATES OF AMERICA (US)	67	1687	699	4099	6552
COMMONWEALTH OF INDEPENDENT STATES (CIS)	5	1527	1040	4023	6595
PEOPLES REPUBLIC OF CHINA (PRC)	9	355	152	3527	4043
JAPAN (JPN)	7	174	59	55	295
INDIA (IND)	0	97	37	127	261
INTERNATIONAL TELECOMMUNICATIONS SATELLITE ORGANIZATION (INTELSAT) (ITSO)	0	90	0	0	90
EUROPEAN SPACE AGENCY (ESA)	0	89	7	49	145
GLOBALSTAR (GLOB)	0	84	0	1	85
FRANCE (FR)	0	64	158	333	555
GERMANY (GER)	0	62	0	1	63
SOCIÉTÉ EUROPÉENNE DES SATELLITES (SES)	0	61	0	0	61
ORBITAL TELECOMMUNICATIONS SATELLITE (GLOBALSTAR) (ORB)	0	58	0	11	69
UNITED KINGDOM (UK)	0	55	1	1	57
EUROPEAN TELECOMMUNICATIONS SATELLITE ORGANIZATION (EUTELSAT) (EUTE)	0	54	0	0	54
CANADA (CA)	0	51	0	5	56
ITALY (IT)	0	29	2	0	31
SPAIN (SPN)	0	26	0	0	26
SOUTH KOREA (SKOR)	0	23	1	0	24
ARGENTINA (ARGN)	0	20	0	1	21
O3B NETWORKS (O3B)	0	20	0	0	20
AUSTRALIA (AUS)	0	19	2	0	21
ISRAEL (ISRA)	0	18	0	0	18
INDONESIA (INDO)	0	18	0	0	18
BRAZIL (BRAZ)	0	17	0	0	17
INTERNATIONAL MARITIME SATELLITE ORGANIZATION (INMARSAT) (IM)	0	17	0	0	17
SAUDI ARABIA (SAUD)	0	15	0	0	15
ARAB SATELLITE COMMUNICATIONS ORGANIZATION (AB)	0	14	0	0	14
TURKEY (TURK)	0	13	0	0	13
SWEDEN (SWED)	0	11	0	0	11
NORWAY (NOR)	0	11	0	0	11

- Countries, international entities, companies having more than 10 payload in orbit. (Source: Space-Track.org)

Satellite Counts vs Gross Domestic Product

COUNTRY	IN ORBIT PAYLOAD COUNT RANKING	GDP RANKING	(GDP COUNT RANK) - (PAYLOAD COUNT RANK)
UNITED STATES OF AMERICA (US)	1	1	0
COMMONWEALTH OF INDEPENDENT STATES (CIS)	2	12	10
PEOPLES REPUBLIC OF CHINA (PRC)	3	2	-1
JAPAN (JPN)	4	3	-1
INDIA (IND)	5	6	1
FRANCE (FR)	6	7	1
GERMANY (GER)	7	4	-3
UNITED KINGDOM (UK)	8	5	-3
CANADA (CA)	9	10	1
ITALY (IT)	10	9	-1
SPAIN (SPN)	11	14	3
SOUTH KOREA (SKOR)	12	11	-1
ARGENTINA (ARGN)	13	21	8
AUSTRALIA (AUS)	14	13	-1
ISRAEL (ISRA)	15	31	16
INDONESIA (INDO)	16	16	0
BRAZIL (BRAZ)	17	8	-9
SAUDI ARABIA (SAUD)	18	19	1
TURKEY (TURK)	19	17	-2
SWEDEN (SWED)	20	22	2
NORWAY (NOR)	21	28	7

- Big economies invest in space more (Source for GDP: Wikipedia based on World Bank data at 2017)
- BUT, CubeSats made reaching space more affordable

Satellites of Turkey

- 15 payloads in orbit in total
- 6 communication satellites: TURKSAT satellites; 3 active
- 4 Earth observation satellites: BILSAT, RASAT, GOKTURK 1 and GOKTURK 2
- 5 CubeSats: ITUpSat-1, TurkSat-3USat, HAVELSAT, BeEagleSat, UBAKUSAT

Cubesats of Turkey

- Developed by **Istanbul Technical University** (ITU), **Space Systems Design and Test Laboratory** (SSDTL), **Prof Alim Rüstem ASLAN**

http://usttl.itu.edu.tr/en/

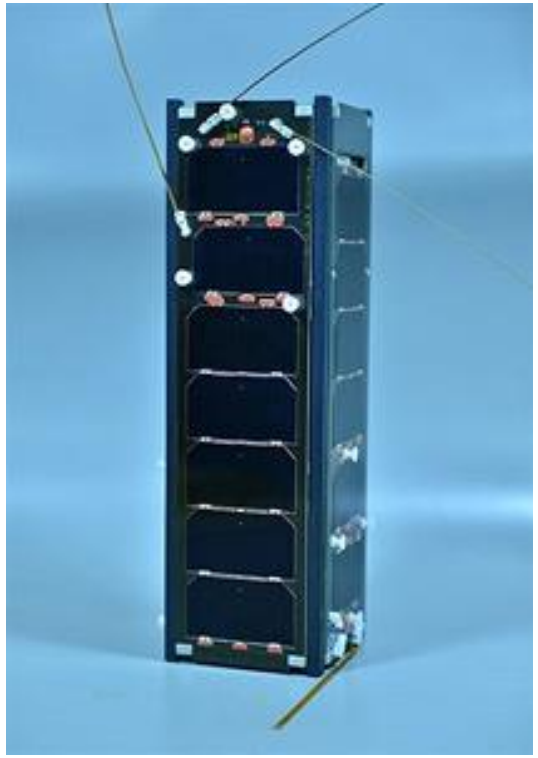
ITUpSAT1

- 1U CubeSat launched in 2009 with Indian PSLV C14
- For technology demonstration and a low resolution camera as payload

(nanosats.eu)

Türksat-3USAT

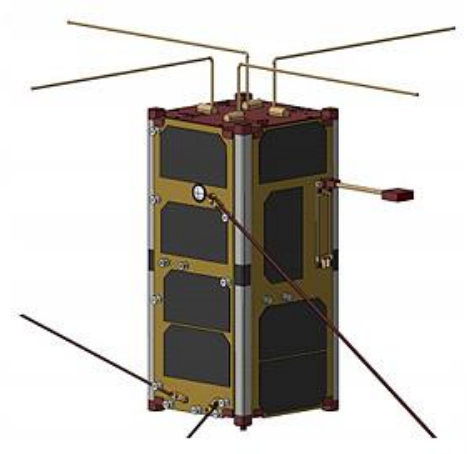
- 3U CubeSat launched in 2013 with CZ-2D
- Payload is a transponder for voice communication.

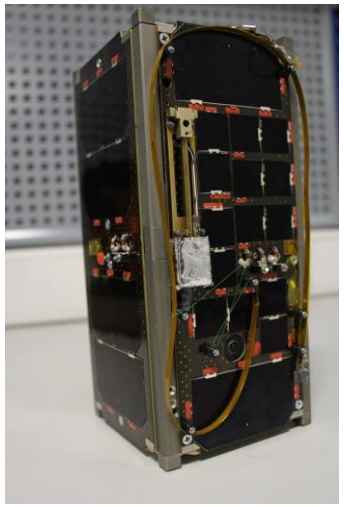


(space.skyrocket.de)

HAVELSAT and BeEagleSat

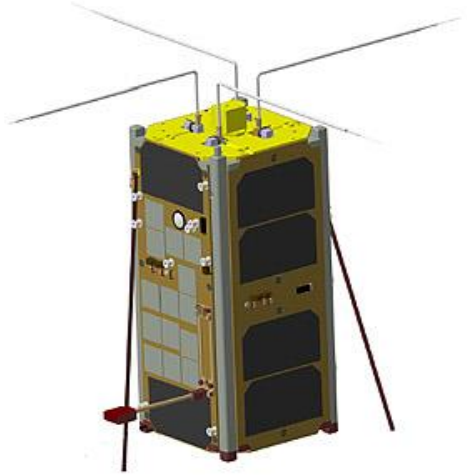
- 2U CubeSats deployed from ISS in 2017.
- Part of QB50 project with multineedle Langmuir probe + X-ray detector in BeEagleat





HAVELSAT

(space.skyrocket.de, nanosats.eu)

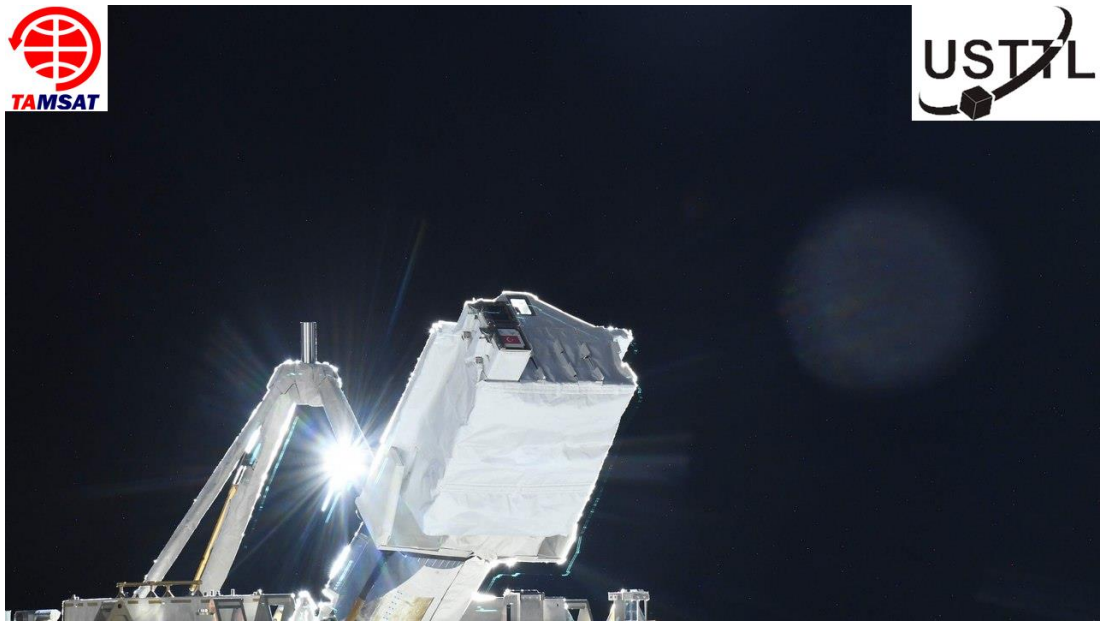


BeEagleSat

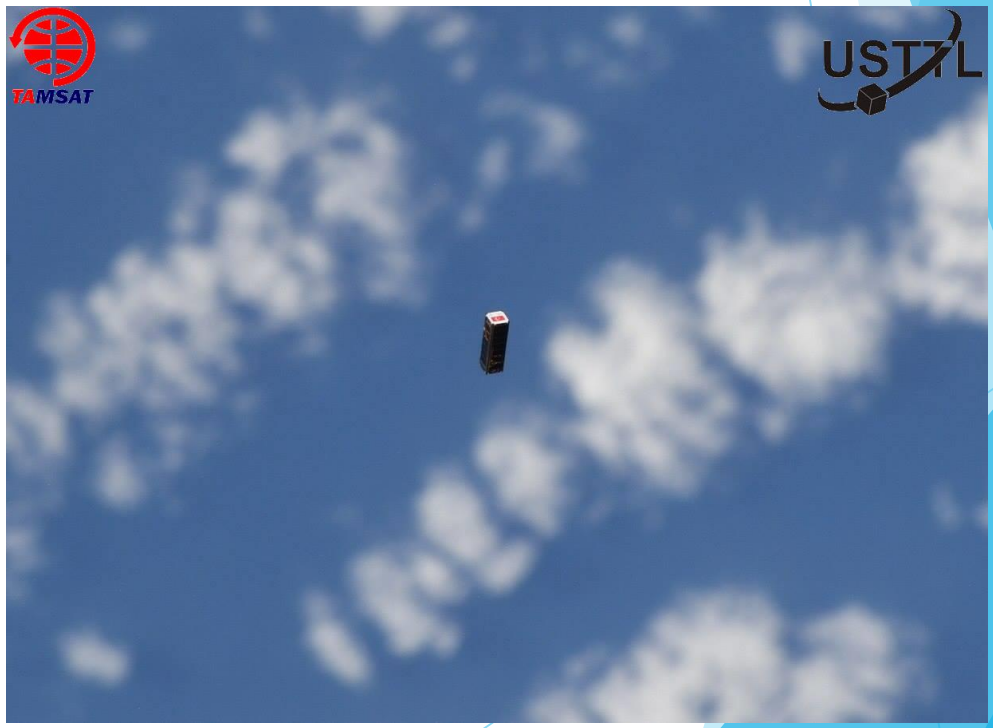
(space.skyrocket.de)

UBAKUSAT

- 3U CubeSat deployed in orbit from ISS in 2018
- Payload is a transponder for amateur radio communication.

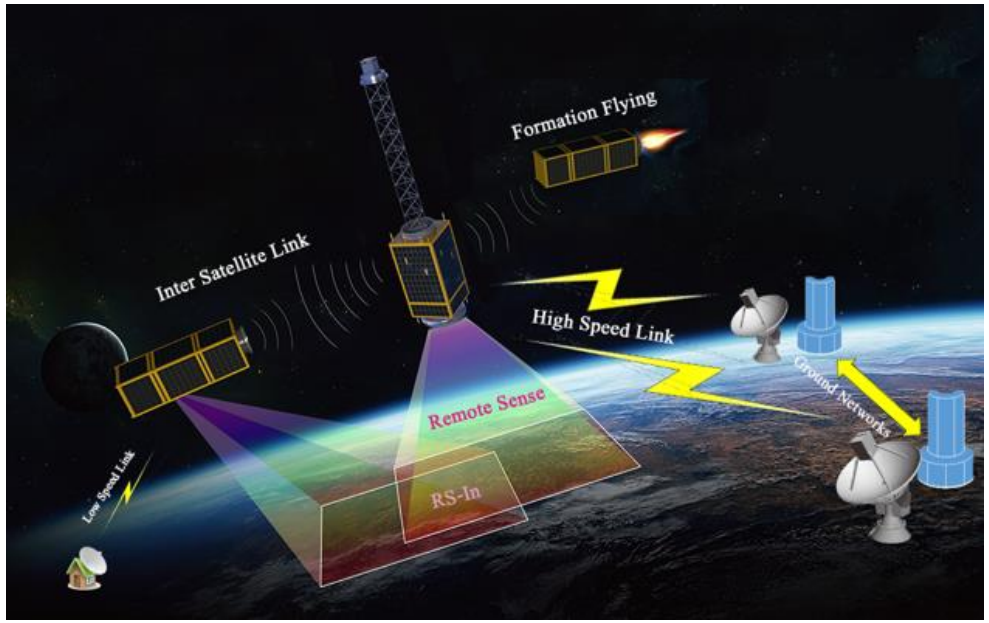


(usttl.itu.edu.tr)



Future CubeSats

- APSCO Student Small Satellite SSS 2B TÜBİTAK-UZAY partnered with partnered with Thailand (Mahanakorn University of Technology)



(apsco.int)

- KılıçSat: AIS payload, ground station in UTAA

Why UTAA into CubeSats?

- To have some science => physics => general relativity
- Scales!
- CubeSats changes the scales: dimensions, most importantly costs!

Scales of UTAA

- Faculty of Aeronautics and Astronautics: ~ 10 Aerospace faculty
- Astronautical engineering: ~ 100 students
- Physicists or general relativists: ~ 5
- Labs? Possibility to use the infrastructure of “Turkish Aerospace” and “Space Research Institute of TUBITAK”.

Gravitomagnetism

- Einstein's gravity nonlinear
- Linearize it => Similar to electromagnetism
- Gravitoelectric effects => Readily there, Newtonian gravity field
- Gravitomagnetism => Study it with increasing precision (e.g. LAGEOS , Gravity Probe B)

Metric: Describing Curved Spacetime

- Metric: gives distances, the Pythagorean theorem

- 3D flat space, Cartesian coordinates:

$$ds^2 = dx^2 + dy^2 + dz^2$$

- 3D flat space, spherical coordinates:

$$ds^2 = dr^2 + r^2\left(d\vartheta^2 + \sin^2\vartheta d\varphi^2\right)$$

- (3+1)D flat spacetime:

$$ds^2 = -c^2dt^2 + dx^2 + dy^2 + dz^2$$

Metric: Describing Curved Spacetime

- Schwarzschild metric, spherically symmetric spacetime:

$$ds^2 = -\left(1 - \frac{2GM}{r}\right) dt^2 + \left(1 + \frac{2GM}{r}\right) dr^2 + r^2 \left(d\vartheta^2 + \sin^2 \vartheta d\varphi^2\right)$$

- Kerr metric, cylindrically symmetric spacetime:

$$ds^2 = -\left(1 - \frac{2GMr}{\rho^2}\right) dt^2 + \frac{\rho^2}{\Delta} dr^2 + \rho^2 d\vartheta^2 + \frac{\sin^2 \vartheta}{\rho^2} d\varphi^2 - \frac{4GMar}{\rho^2} \sin^2 \vartheta d\varphi dt$$

where

$$\Delta = r^2 - 2GMr + a^2, \qquad \rho^2 = r^2 + a^2 \cos^2 \theta, \qquad a = J/M.$$

Following arXiv:1810.11785

Test of gravitomagnetism with satellites around the Earth

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(Dated: March 5, 2019)

We focus on the possibility of measuring the gravitomagnetic effects due to the rotation of the Earth, by means of a space-based experiment that exploits satellites in geostationary orbits. Due to the rotation of the Earth, there is an asymmetry in the propagation of electromagnetic signals in opposite directions along a closed path around the Earth. We work out the delays between the two counter-propagating beams for a simple configuration, and suggest that accurate time measurements could allow, in principle, to detect the gravitomagnetic effect of the Earth.

Metric for Earth

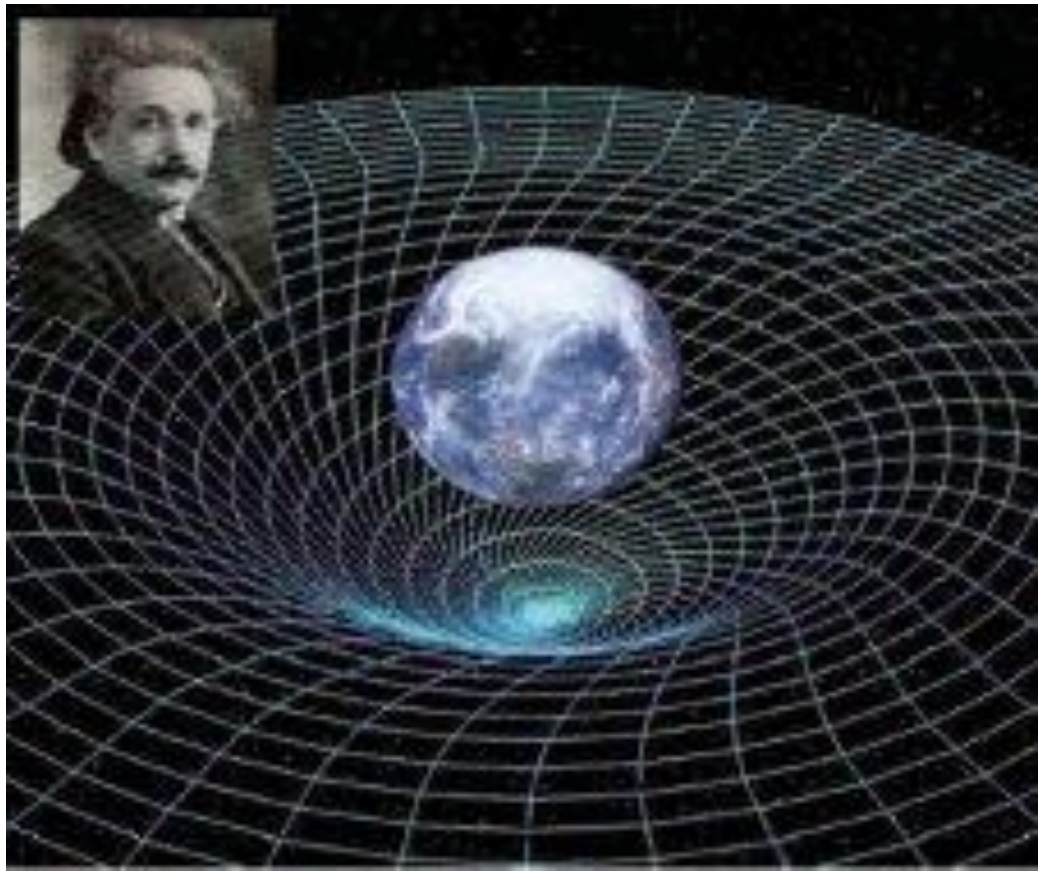
- Consider the Kerr metric for the equatorial plane at the leading order in rotation parameter:

$$ds^2 = -\left(1 - \frac{2GM_E}{c^2 r}\right) c^2 dt^2 + \left(1 + \frac{2GM_E}{c^2 r}\right) dr^2 + r^2 d\varphi^2 \; - \frac{4GJ_E}{c^2 r} d\varphi dt$$

- Consider coordinates co-rotating with a satellite

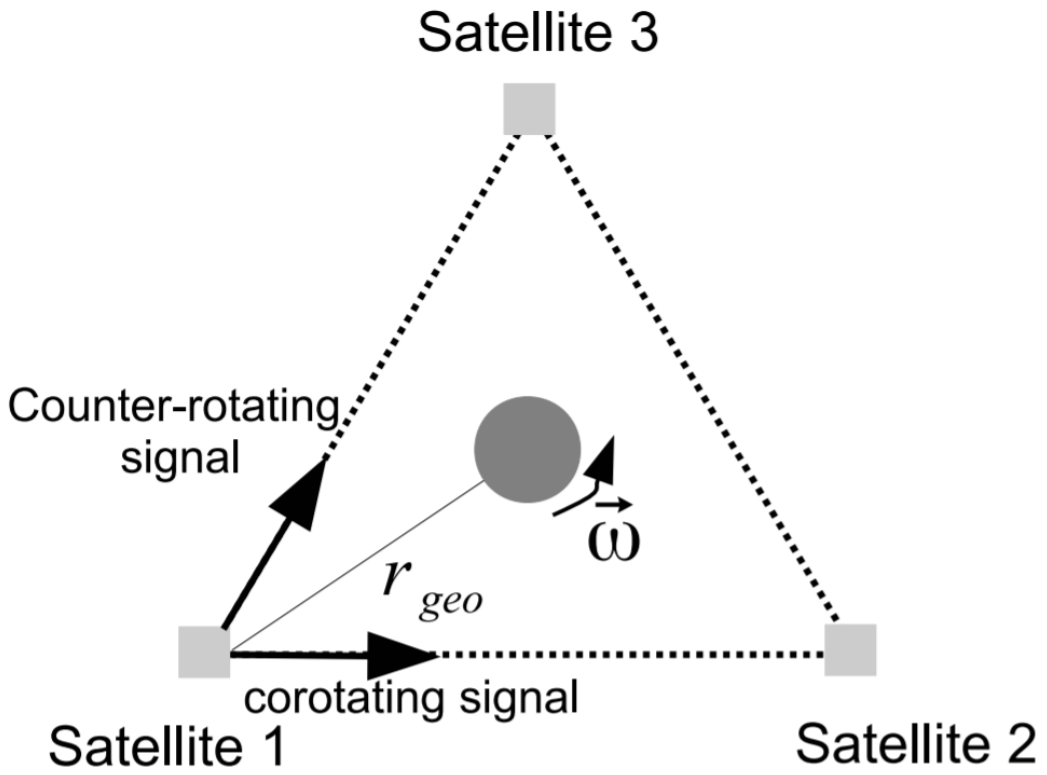
$$ds^2 = -\left(1 - \frac{2GM_E}{c^2 r} - \frac{4GJ_E\omega_E}{c^4 r} - \frac{\omega_E^2 r^2}{c^2}\right) c^2 dt^2 - 2\left(\frac{2GJ_E}{c^2 r} + \omega_E r^2\right) d\phi dt$$
$$+ \left(1 + \frac{2GM_E}{c^2 r}\right) dr^2 + r^2 d\phi^2$$

Earth's Rotation and Spacetime



(Source: nasa.gov, "In Search of Gravitomagnetism")

Rotating Around Earth: Direction matters!



(Source: arXiv:1810.11785)

Rotating around Earth

- Scales:

$$\Delta t = \Delta t^{SR} + \Delta t^{GR} \Rightarrow \Delta t^{SR} \approx \frac{\omega_E r^2}{c^2}, \qquad \Delta t^{GR} \approx \frac{G J_E}{c^4 r},$$
$$\Rightarrow \Delta t^{SR} \simeq 10^{-7}\ \mathrm{s}, \qquad \Delta t^{GR} \simeq 10^{-17}\ \mathrm{s}$$

- For GEO, almost one rotation in 1s.

- CubeSats? Number of satellites? LEO and perturbations? Atomic clock on a chip accuracies? Other possibilities to measure gravitomagnetic effects with CubeSats?

Conclusions

- With CubeSats, science missions are in the reach of UTAA.
- Conclusion after the training/forum, first to do: have your first CubeSat(s), make it work, may put some atomic clock on a chip do some standard physics and engineering
- Conclusion after the forum: Go for the new horizons in science with CubeSats. Breakthroughs in science with CubeSats possible!?