

- I. Venus Long-Life Surface Platform
- II. Venus III book
- III. Venus 2016 Conference Oxford
- IV. Open Mic I: Venus UHF data relay standard?
- V. Open Mic II: Venus 360 VR film



Colin Wilson
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ESA Call for New Scientific Ideas

- *“This call aims at stimulating the emergence of **new and innovative science ideas** based on technologies not yet sufficiently mature, possibly to become potential candidates for **future M or L mission Calls** in the ESA Science Programme”.*
- i.e. future >€400M€ missions
- Call issued **Feb 2016**; proposals submitted **Sep 2016**
- Essentially, this is a **horizon scanning** exercise for ESA.
- May guide the topics for ESA’s Technology Reference Mission studies. Past examples include:
 - **Venus Entry Probe (VEP)** – 2004 – 2x orbiter + balloon + 100 g microprobes
 - **Planetary Entry Probe (PEP)** – 2010 – ‘generic’ descent probe for Venus, Saturn, Uranus, Neptune
- Could lead to ESA mission study, technology support.

ESA Call for New Scientific Ideas

- For ESA M-class mission call (550M€ cost cap), the European Venus community is united in its support for a single Venus proposal: EnVision (a radar-equipped orbiter).
- Our initial Letter of Intent therefore listed all *in situ* science options: probes, balloons, landers.
- Because balloons & entry probes have been studied before, we focussed all our efforts on a mission element never studied before by ESA: ***an ambient temperature surface station with seismometry as its core goal.***

Venus Long-Lived Surface Platform (VL²SP)

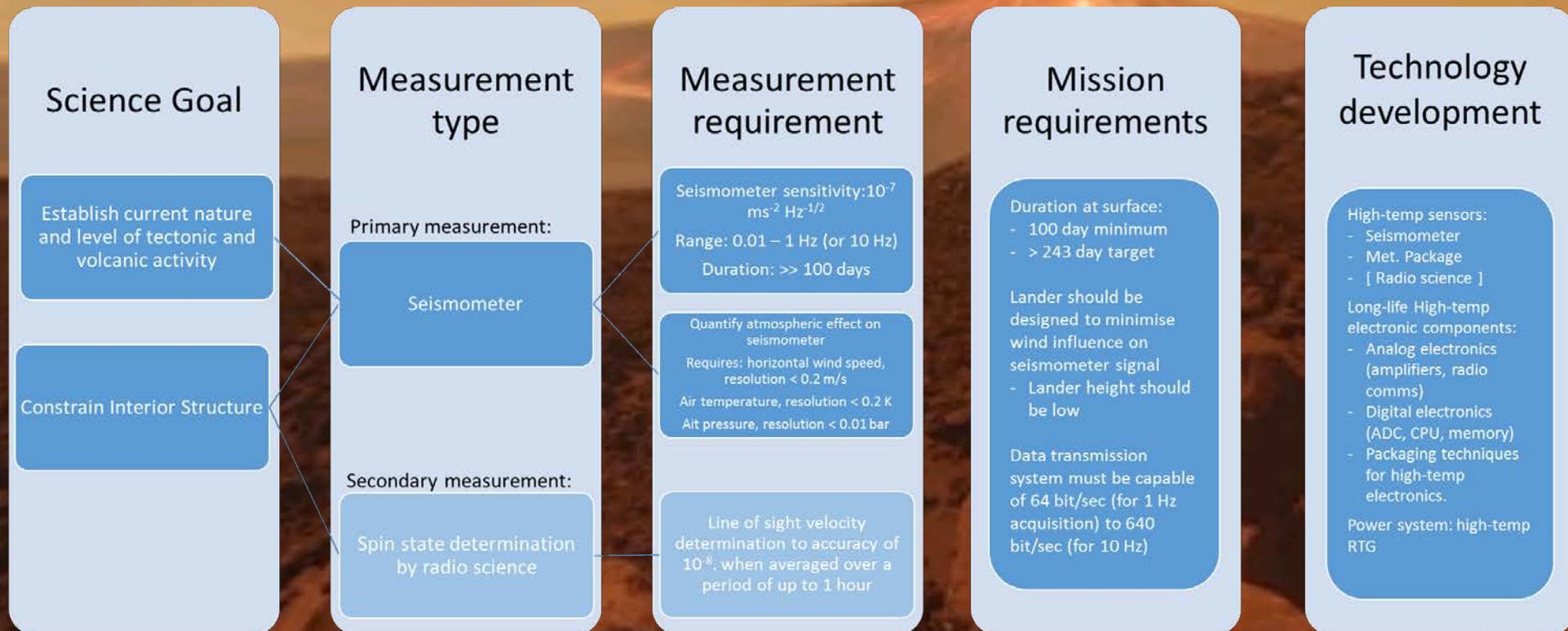
Science goal

Is Venus geologically active? How?

- Establish level and style of seismic activity
- Constrain interior structure
- Measure spin rate and axis variations
- Seismic signs of volcanism / tectonism
- *[measure Interior Heat flux]*
- *[measure changes in volcanogenic gases]*

Venus Long-Life Surface Platform (VL²SP)

- The chart below outlines the flow down of core science goals to mission requirements and technology development



Venus Long-Life Surface Platform (VL²SP)

- Lifetime of >100 Earth days
- Core Payload:
 - Seismometer
 - p , T , w sensors to quantify atmospheric influence on seismometer
 - Radio science
- There are many additional measurements which would be complementary:
 - Heat Flux sensor
 - Image sensor
 - SiC gas sensors
 - Electric field sensors (measure conductivity, d.c. electric field)
 - But we focus on core payload first, to keep design reference mission simple



Venus Long-Lived Surface Platform (VL²SP)

- Power: battery or (preferably) RTG
 - Baseline: Salazar et al. 2014 specify 24 kg RTG providing 26 W of electrical power.
 - We imagine 1-2 of these units.
- Data
 - Minimum 64 bits/sec
 - 3-axis seismometer @ 16 bits / sample x 1 Hz + HK
 - Nominal 640 bits/sec
 - as above but 10 Hz sampling.
- SiC CPU:
 - Assume very little onboard memory (~ few kbits)
 - ADC of all sensor channels
 - Live transmission to space
 - (data relay orbiter is assumed but not part of VL²SP proposal)

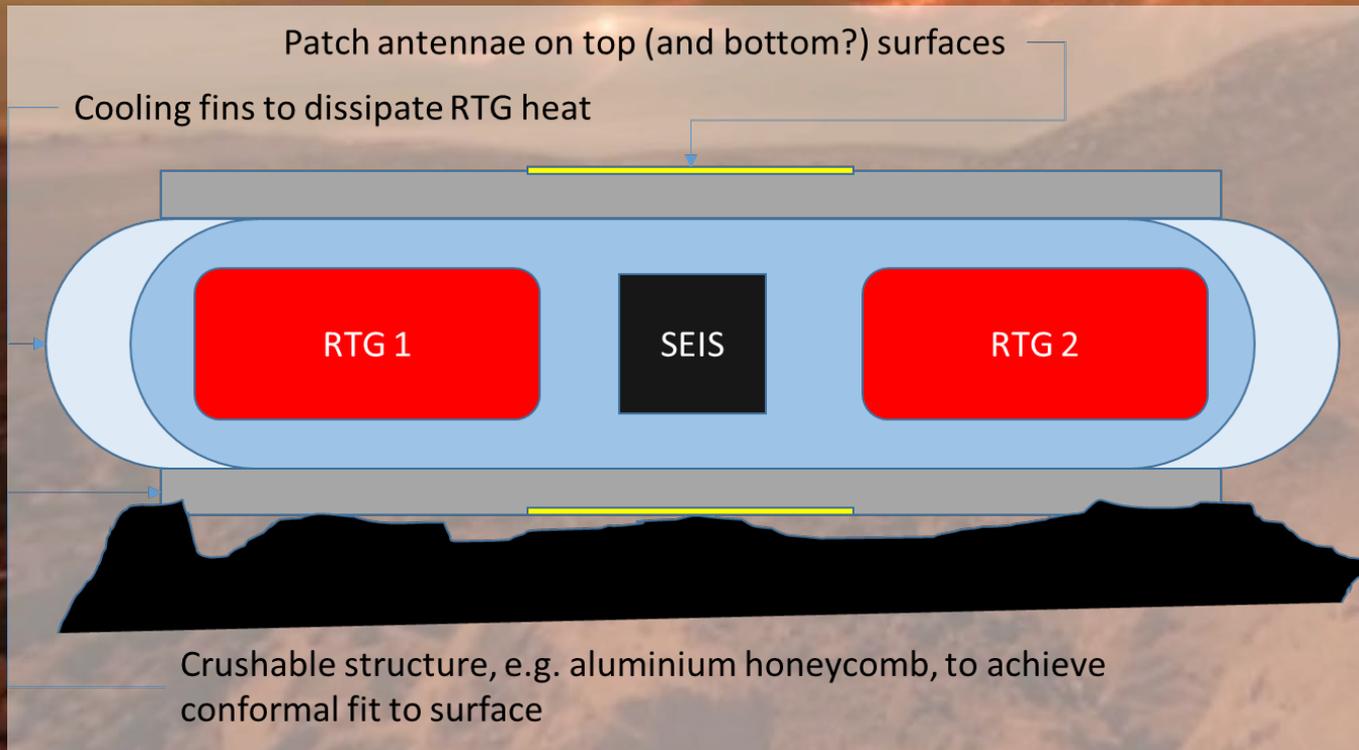
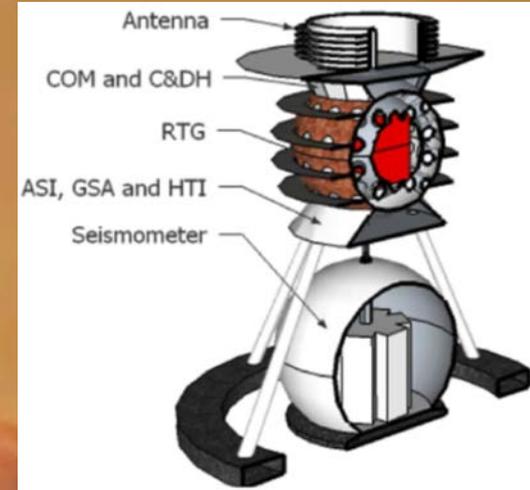
Venus Long-Lived Surface Platform (VL²SP)

- Mission scenario:
 - Option A: stand-alone entry probe
 - Requires EDLS design
 - Option B: delivered to surface by e.g. entry probe.
 - Entry probe would provide descent phase measurements including chemical profiles, and landing site imagery.
 - Would need VL2SP deployment system to minimise wind coupling.
- I understand that NASA GRC are developing similar proposals e.g. LLISSE study (see Tibor Kremic talk).

Possible mechanical designs

Simplest option: low and flat disc, to minimise wind noise.

Emplaceable package (like Insight) may be considered, depending on mission scenario, but seems unlikely for a standalone M-class mission.



HADES lander design
(Boll et al. 2015)

Exploration context

- Sustained operation at the surface is a natural precursor to more complex surface missions
- Demonstrate subsystems
 - Power, thermal, comms...
 - Extreme environment packaging
- Characterize surface environment
 - Winds, particulates, illumination...
- Trailblazer for surface explorers...



Flyby

Orbital science

Descent phase science

Soft landing & Short duration operation on surface

Sustained operation on surface

Mobility to explore & sample surface

Eventually:
sample return

Venus Long-Lived Surface Platform (VL²SP)

Colin Wilson (Oxford, UK), Carl-Mikael Zetterling (KTH, SE), Tom Pike (Imperial, UK)

- Proposal was submitted in Sep 2016 – decision expected soon
- We hope this will lead to ESA mission studies & technology development funding.
- *And remind ESA that Venus is a scientifically compelling destination...*
- Proposal document is available on ArXiv:

<https://arxiv.org/abs/1611.03365>

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Venus III book

- To be published as Special Issue of Space Science Reviews (Springer)
- Each chapter will be electronically accessible as a Space Science Review paper
- Editorial Board:
 - Bruno Bézard (Chair of editorial board)
 - Chris Russell
 - Takehiko Satoh
 - Sue Smrekar
 - Colin Wilson

Venus III Chapter list

	Title	Author list
1	Introduction	Taylor , Svedhem, Head
2	Venus interior structure and dynamics	Sotin , Davaille, Lenardic, Smrekar
3	Venus surface composition and weathering	Gilmore , Helbert, Smrekar, Treiman
4	Venus Atmospheric structure and radiative balance	Limaye , Grassi, Migliorini, Mahieux, Tellmann, Titov
5	Atmospheric dynamics	Sanchez-Lavega , Lebonnois, Imamura, Read, Luz
6	Composition and chemistry of the neutral Atmosphere	Marcq , Mills, Sandor, Vandaele
7	Clouds and aerosols	Titov , Ignatiev, McGouldrick, Wilquet, Wilson
8	Solar Wind interaction with Venus and impact on its atmosphere	Barabash , Futaana, Wieser, Luhmann
9	Aeronomy of Venus	Gérard , Bougher, Drossart, Pätzold, Piccioni, Lopez-Valverde
10	Evolution of the atmosphere and climate of Venus	Bullock , Grinspoon, Zahnle, Elkins-Tanton, Lammer
11	Future of Venus research and exploration	Glaze , Wilson, Limaye, Zasova, Nakamura

Venus III book - status

- **9 of 11 chapters have been received** in draft form
 - 2 out of 11 promised delivery in November – *hint: it's Dec now* 😊
- 5 of 11 chapters have been internally reviewed by editorial board for omissions / overlap with others, feedback sent to authors
- **First chapter is now ready for submission.** *Spa. Sci. Rev.* submissions page has been opened for submission of final chapters.
- Other lead authors encouraged to ***finalise and submit*** their chapters!
- Thanks all for your hard work. Please continue momentum.

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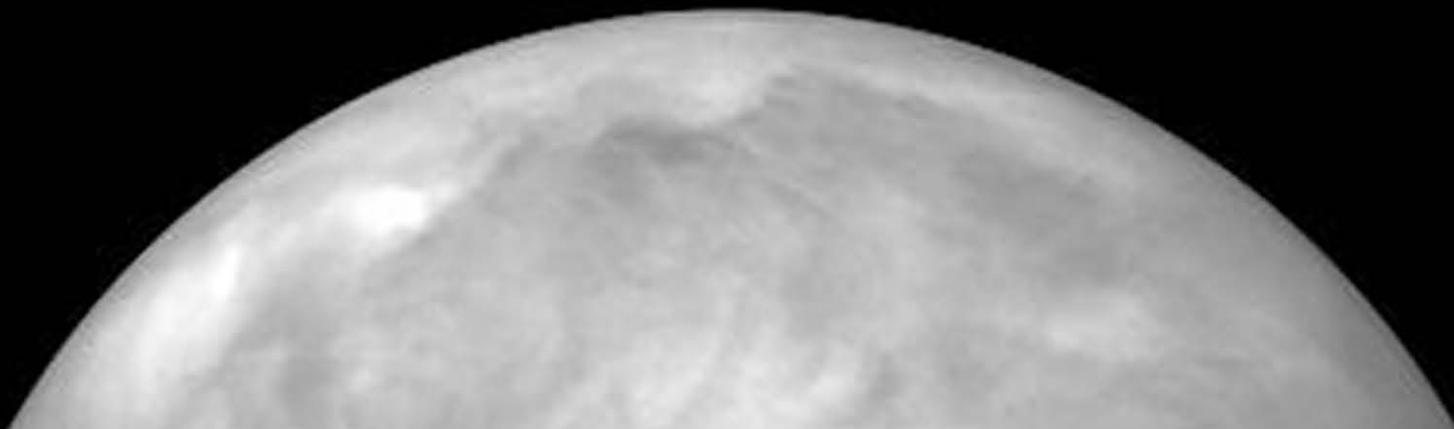
International Venus Conference 2016

4 – 8 April 2016 - www.venus2016.uk

A beautiful old collegiate Oxford venue

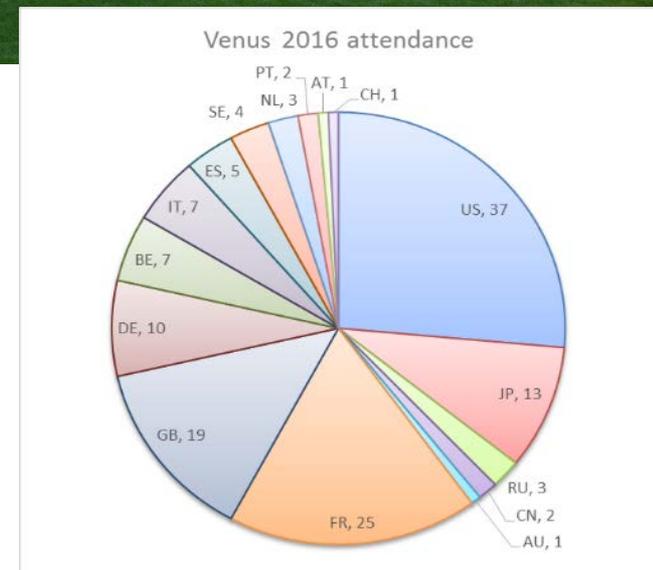
Subsidised conference fee, student travel support

Mark your calendars...



Venus 2016 conference, Oxford

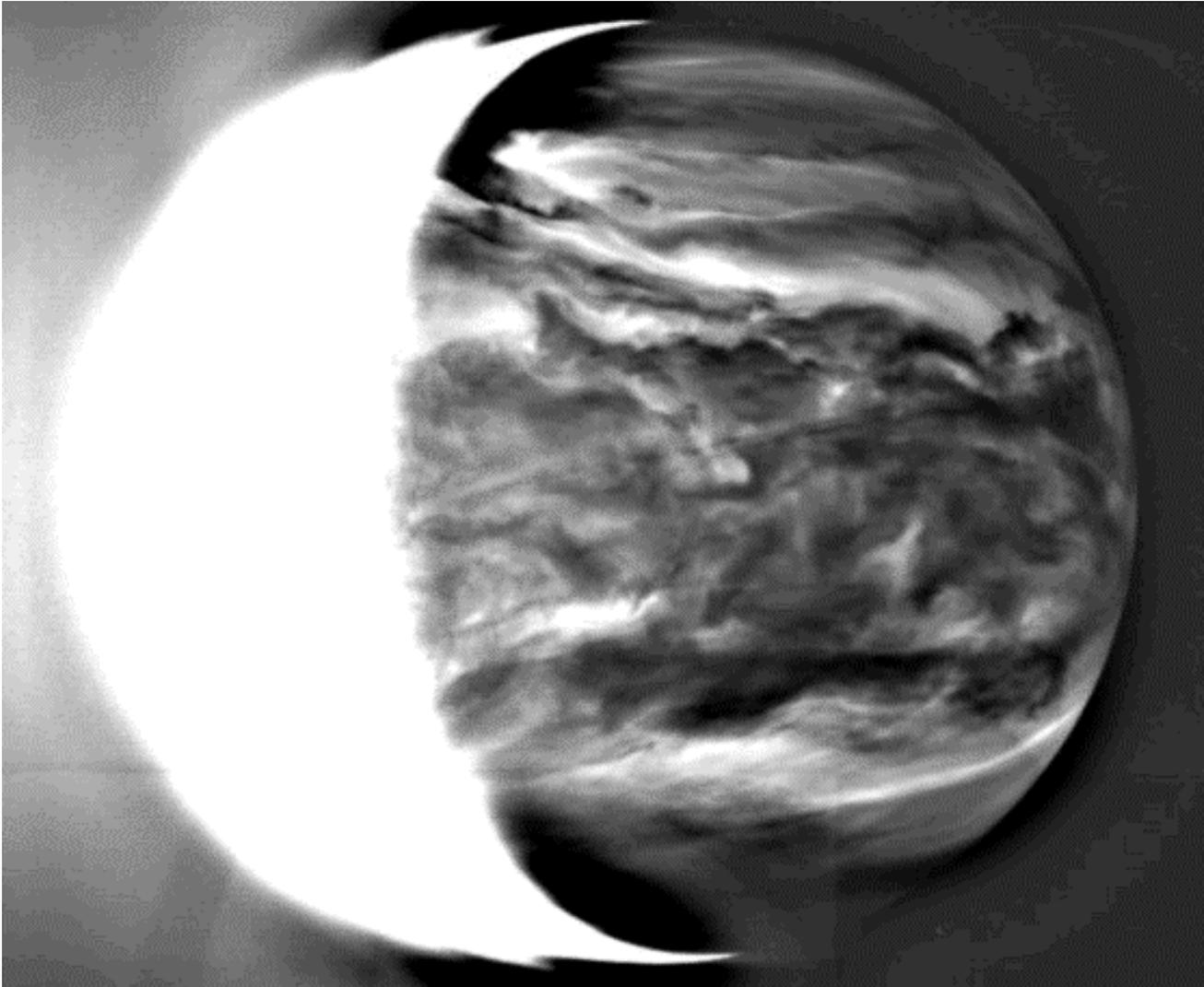
- **140** participants
- **16** countries
- **21** “early career” scientists (PhD students and 1st year postdocs) supported with accommodation costs & registration fee
- Sponsors included EuroVenus, IAMAS, ESA, Univ. Oxford.
- VEXAG provided travel support to one lucky student- many thanks!



Venus 2016 conference, Oxford

- Conference covered all aspects of Venus science from its interior and surface to its atmosphere and magnetosphere.
- Spanned a wide range missions from VeGa balloons, through Venus Express and onwards to Akatsuki and future missions.
- Some highlights (next slides):

First results from Akatsuki



- Covered in *Nature*, along with a pro-Venus editorial

Venus Express legacy session

- VEx P.I.s gave overviews of their instrument, salient results and data archive.
- Videos on youtube, can be accessed via eurovenus.eu website



Looking ahead...

- Akatsuki results!
- Bepi Colombo flyby
- DAVINCI & VERITAS (in no particular order!)
- EnVision
- VAMP
- EMPIRE manned flyby

*We look forward to Venus 2018 conference
- possibly in Japan... 😊*

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Working Group for Venus data relay?

- At Mars, there is an agreed UHF protocol for data relay from landers/rovers.
- Establishing this at Venus would be beneficial for all in situ proposals, in particular long-lived ones.
- Reduces requirement to carry one's own data relay orbiter.
- Increases data return from *in situ elements* and also for *cubesats/smallsats*.
- Helps to measure *position* and *velocity* of in situ elements.

Requirements of a Venus data relay standard

- Capable of 1- or 2-way communication
- Should be at a frequency where atmosphere is largely transparent (e.g. UHF or S-band)
- Should be small and light: ***low resource requirement*** for orbiter.
- Should aid ***position determination*** of in situ elements. (e.g. monitor Doppler shift of received frequency)
- ***Bonus feature***: passive listening mode could be used to detect RF emission from lightning.

Venus data relay standard

- Venus mission developments underway in US, Europe, Russia, China, India
- COSPAR-sponsored IVEWG may be an appropriate body to support a Venus data relay working group, so that we can have discussions with e.g. China.
- Please consider this in your roadmaps.
- ***Vision 2050*** for Venus should certainly include data relay infrastructure, maybe even Venus GPS(!?).
- Your advice / support / participation would be welcome!

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EuroVenus outreach films

- Can be found via www.eurovenus.eu
 - 6x ~10 minute episodes
 - Intro
 - Winds
 - Temperature
 - Volcanoes (SO₂)
 - Transit
 - Future
 - Full documentary – 52 minutes
 - Venus Express legacy session videos
 - 360° VR film
 - All produced by White Fox Pictures (Lyon), with EU-funding
- 

360° VR film: A Journey to Venus

- Join astronomers as they observe Venus from Hawaii
- Step inside the domes & control rooms at CFHT & IRTF
- Experience what it's like to step on the surface of Venus*



- Great for outreach! Please use & share widely!
- Best on VR headsets e.g. Oculus Rift / Gear VR
- Find it on youtube (search "*Journey to Venus 360*")
- I will share link to VEXAG on facebook
- I can send you original file for offline use

**(pressure temperature & CO₂ not included)*

That's all from me.
Sorry I couldn't join you in person!

Colin Wilson
Oxford University

