

The purpose of this talk

- To ask some questions
- To suggest methods for
 - getting answers to the questions
 - gaining consensus on a common vision
 - designing the resulting systems
 - implementing the designs

System Engineering for Civil Timekeeping

À la recherche du temps perdu

Rob Seaman

National Optical Astronomy Observatory

Tucson, AZ

System Engineering for Civil Timekeeping

In search of lost time

Rob Seaman

National Optical Astronomy Observatory

Tucson, AZ

Time has been lost

I) *in characterizing the problem*

II) *in capturing engineering requirements*

III) *in engaging the stakeholders*

Time is in danger of being lost

IV) *Atomic time and Time-of-day
are fundamentally two different things*

I) To characterize any problem

- Examine it in context
- Contrast it with the alternatives
- Explore a vision and mission
- State a concept of operations

Ask yourself, what is this thing in itself, by its own special constitution? What is it in substance, and in form, and in matter? What is its function in the world? For how long does it subsist?

– *Marcus Aurelius*

What is civil timekeeping?

To compare and contrast

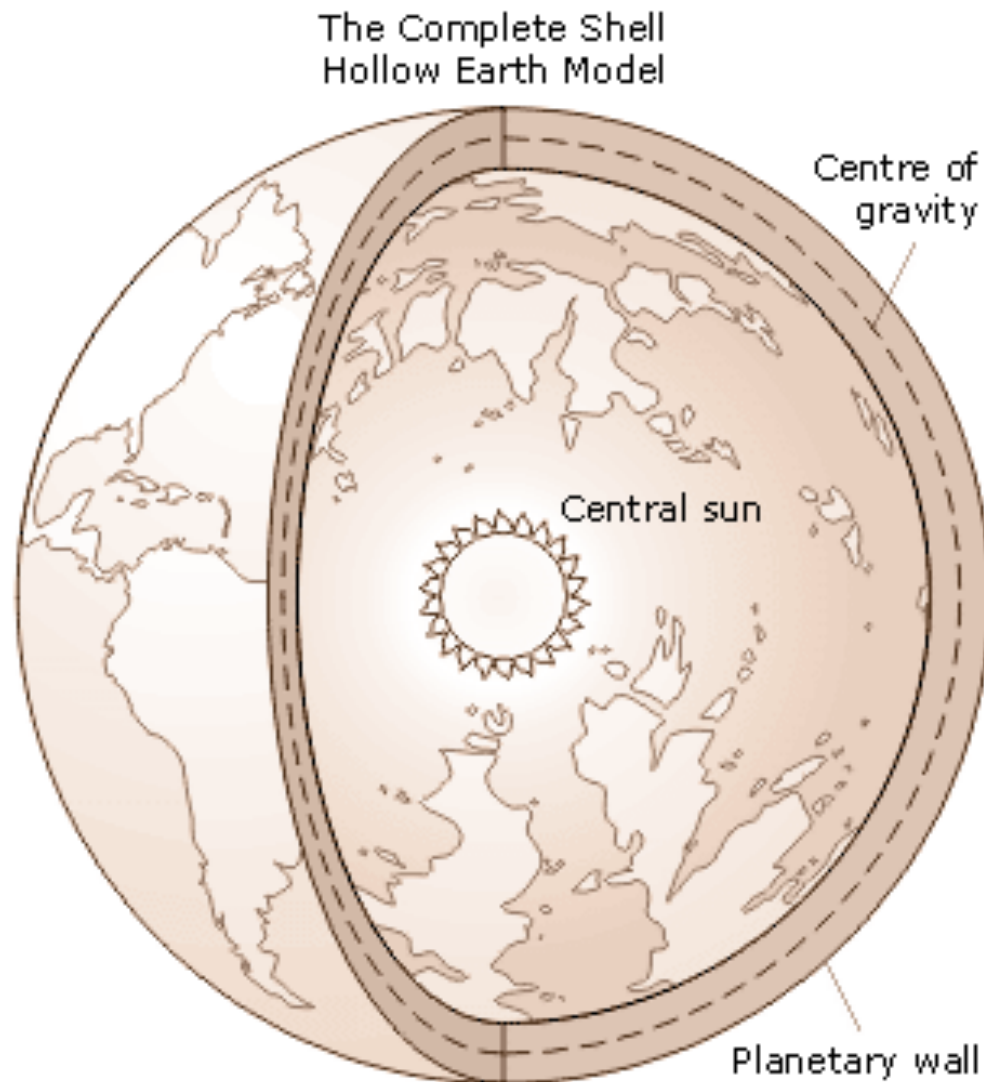
- Need alternative models of time-of-day
- Difficult to come by – only one Earth
- Many Science Fiction examples:
 - Pellucidar
 - Barsoom
 - Caves of Steel
 - Nightfall
 - Ringworld

To compare and contrast

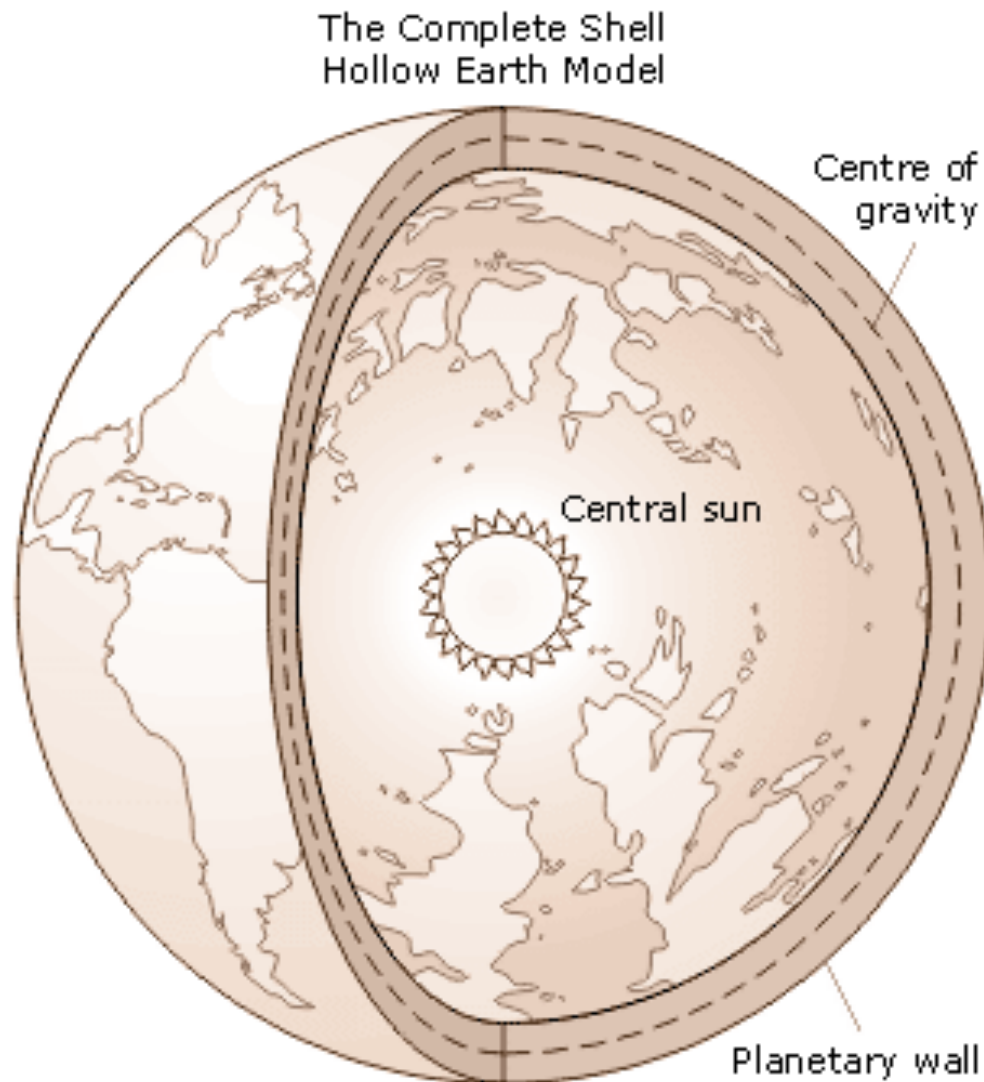
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} We will focus on
Edgar Rice Burroughs

Timekeeping in Pellucidar, or...



“It’s Always Sunny in Pellucidar”



“The long, Pellucidarian day dragged on.”

“It was the **same day** upon which I had broken through the earth's crust from the outer world thirty-six years before, and it was exactly the **same time of day** – high noon – for the stationary sun still stood at zenith. It was the same day and hour that this world was born, the **same day and hour** that would see its death-the eternal day, the eternal hour, the eternal minute of Pellucidar.”

– *Edgar Rice Burroughs*

Timekeeping in Pellucidar

- Step 1: Problem statement:

How do you tell time if the Sun never moves?

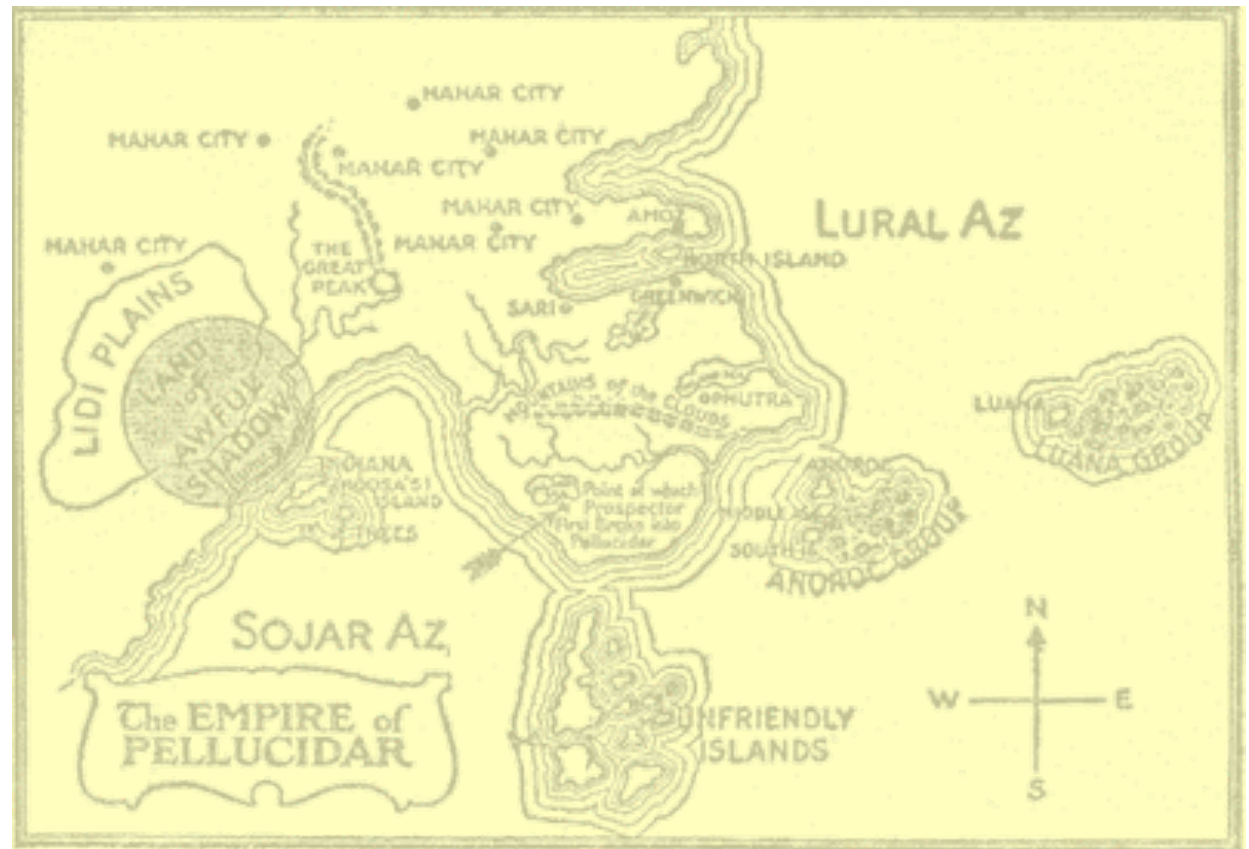
- Step 2: Collect engineering requirements

AT THE
Earth's **CORE**
EDGAR RICE BURROUGHS



The Moon of Pellucidar

- Rotates on axis
- Stationary, does not orbit the inner Sun
- “Land of Awful Shadow”



“I saw a chance to give time to Pellucidar”

“...using **this mighty clock, revolving perpetually in the heavens**, to record the passage of the hours for the earth below. Here should be located an observatory, from which might be flashed by wireless to every corner of the empire the correct time once each day”

– *Edgar Rice Burroughs*

Timekeeping in Pellucidar

- Step 1: Problem statement:

How do you tell time if the Sun never moves?

- Step 2: Collect engineering requirements

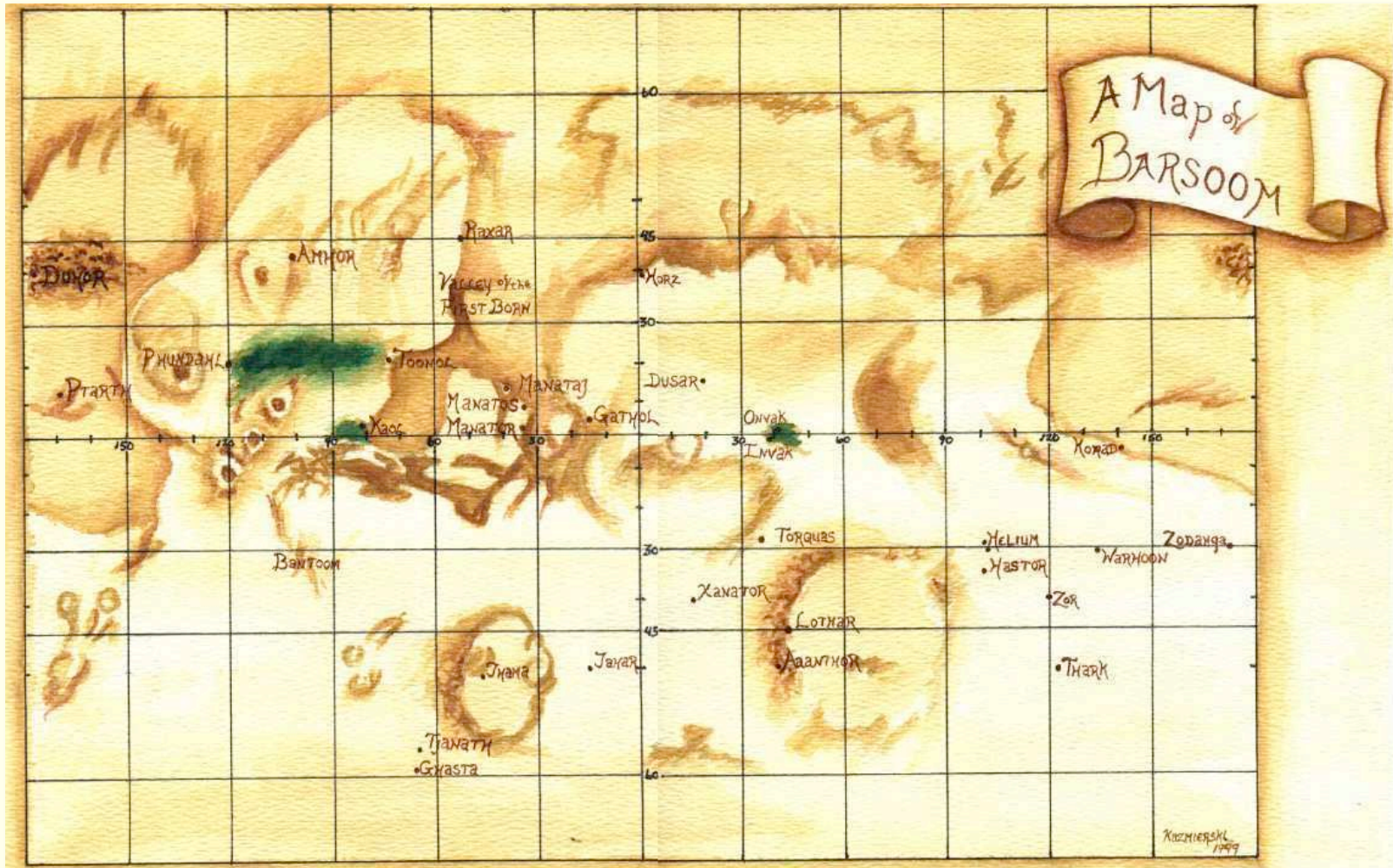
...

- Step N: Proposed solution:

1) *Astronomical observations*

2) *Broadcast time signals*

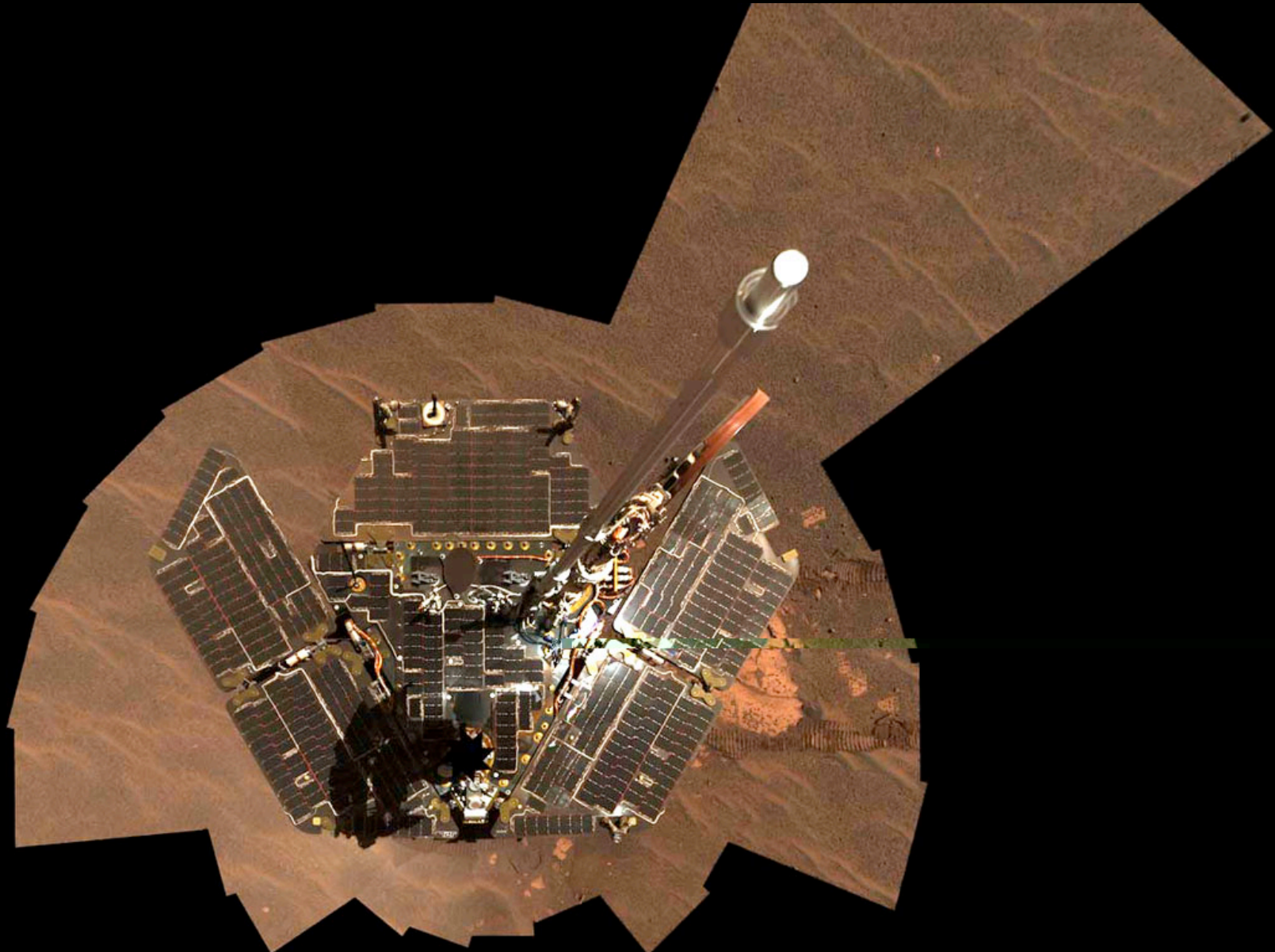
Timekeeping on Barsoom (Mars)





A typical day on the LEAPSECS mailing list

Self-portrait of Opportunity



Timekeeping on the *real* Mars

· MARS ·

MER-B 18:14:24

Sol 2736

**19:15:30 MTC
MSD 48971.802**

**Ls 10.80°
Early SH Autumn**

· EARTH ·

14:25:00 UTC

**2011-10-05
MJD 55839.601**

10:25:00 EDT

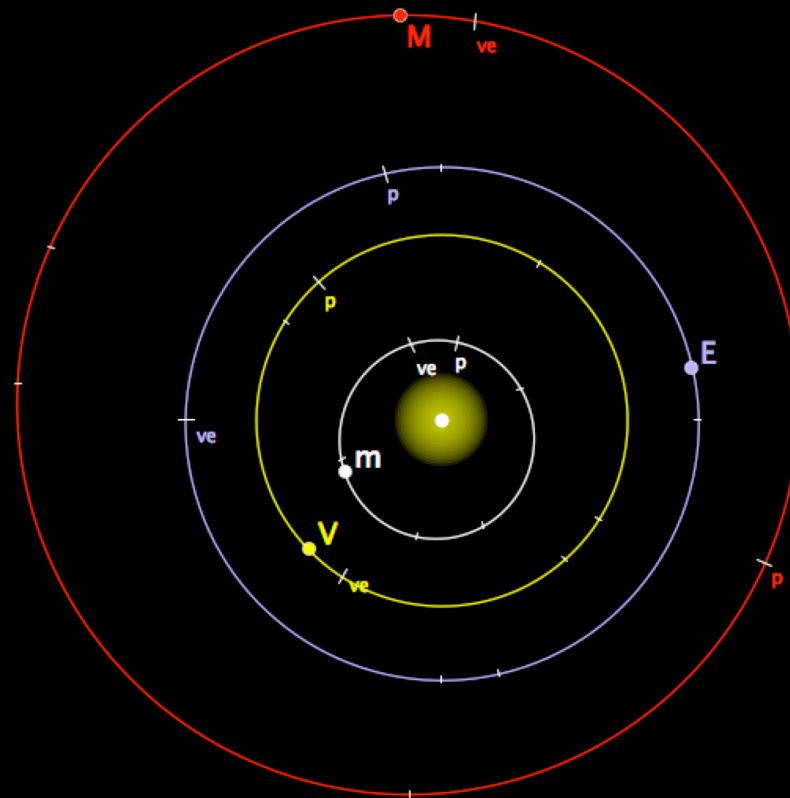
**2011-10-05
OWLT 14:50 min**

<http://www.giss.nasa.gov/tools/mars24/>

Mars' orbit is more eccentric

NASA GISS

Mars24 6.0.3

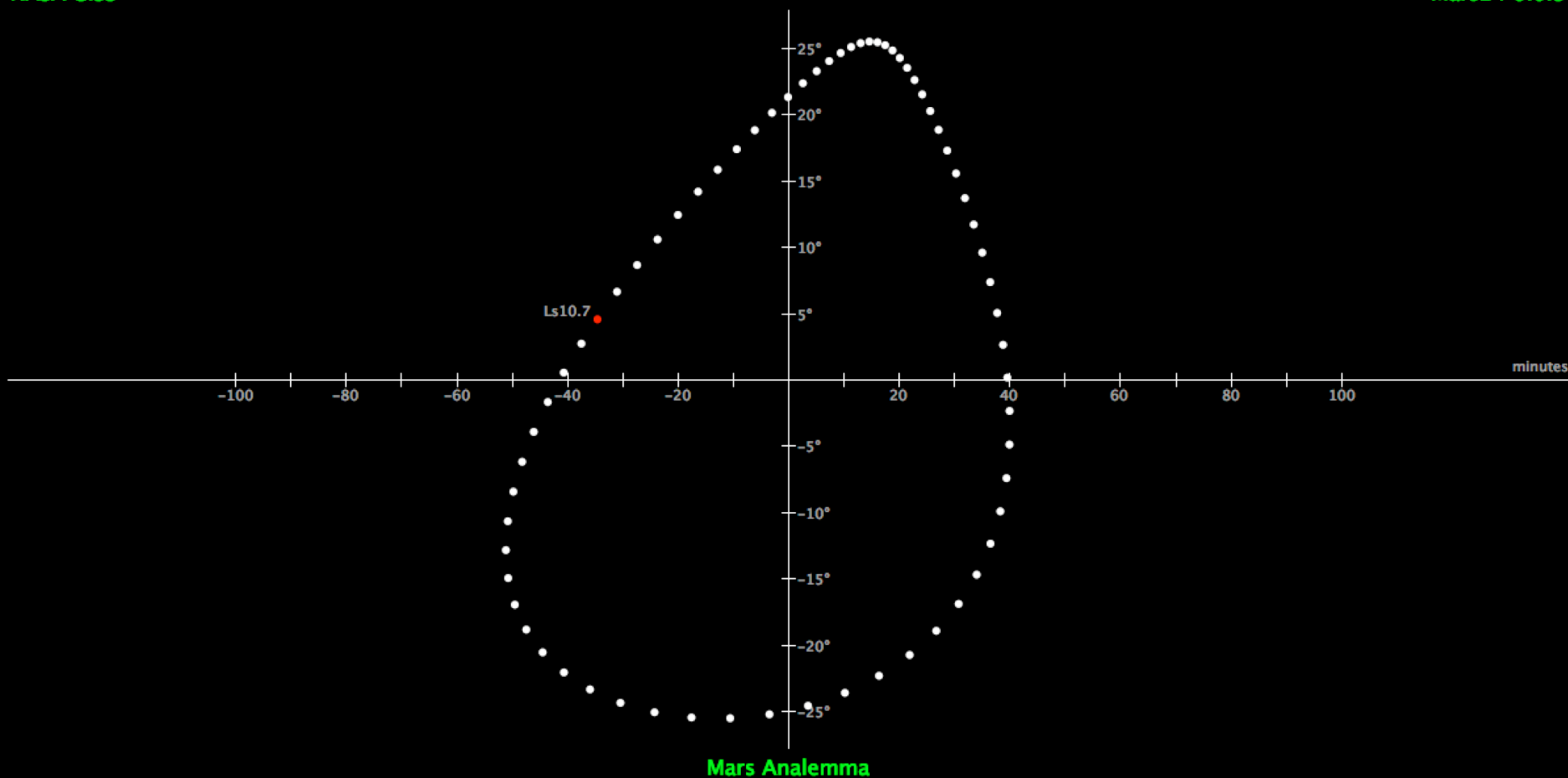


Orbital Positions of the Inner Planets

So the equation of time makes larger excursions

NASA GISS

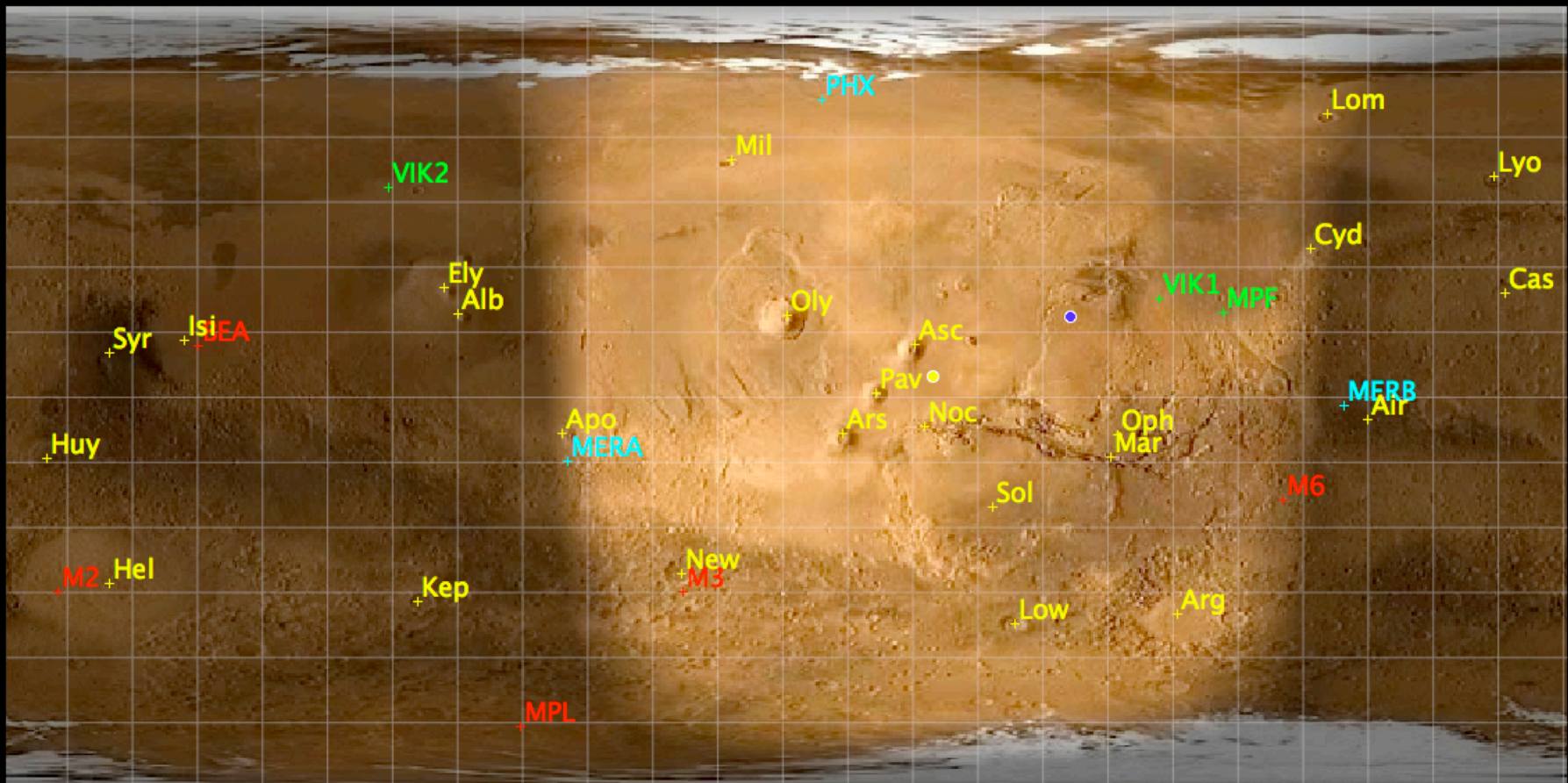
Mars24 6.0.3



And the Mean Solar Time requirement is emphasized

NASA GISS

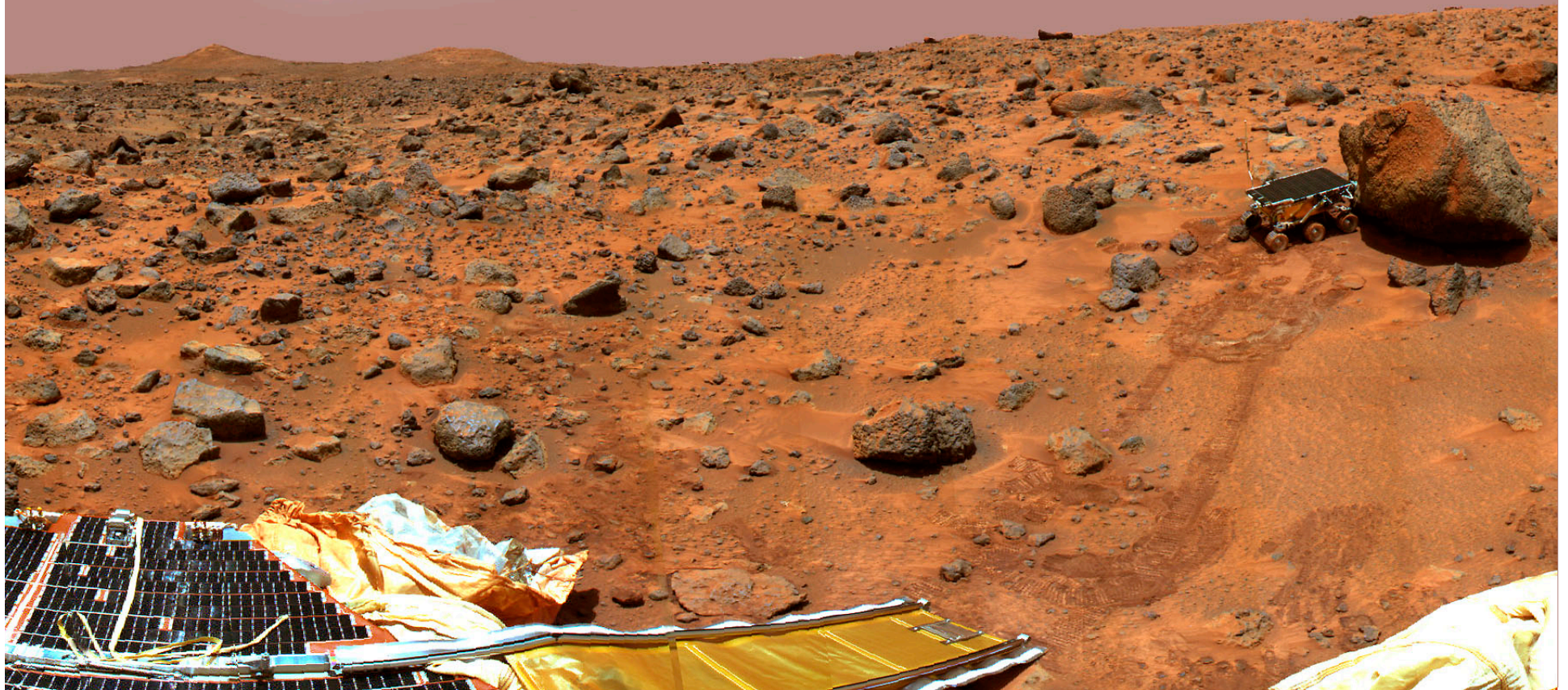
Mars24 6.0.3



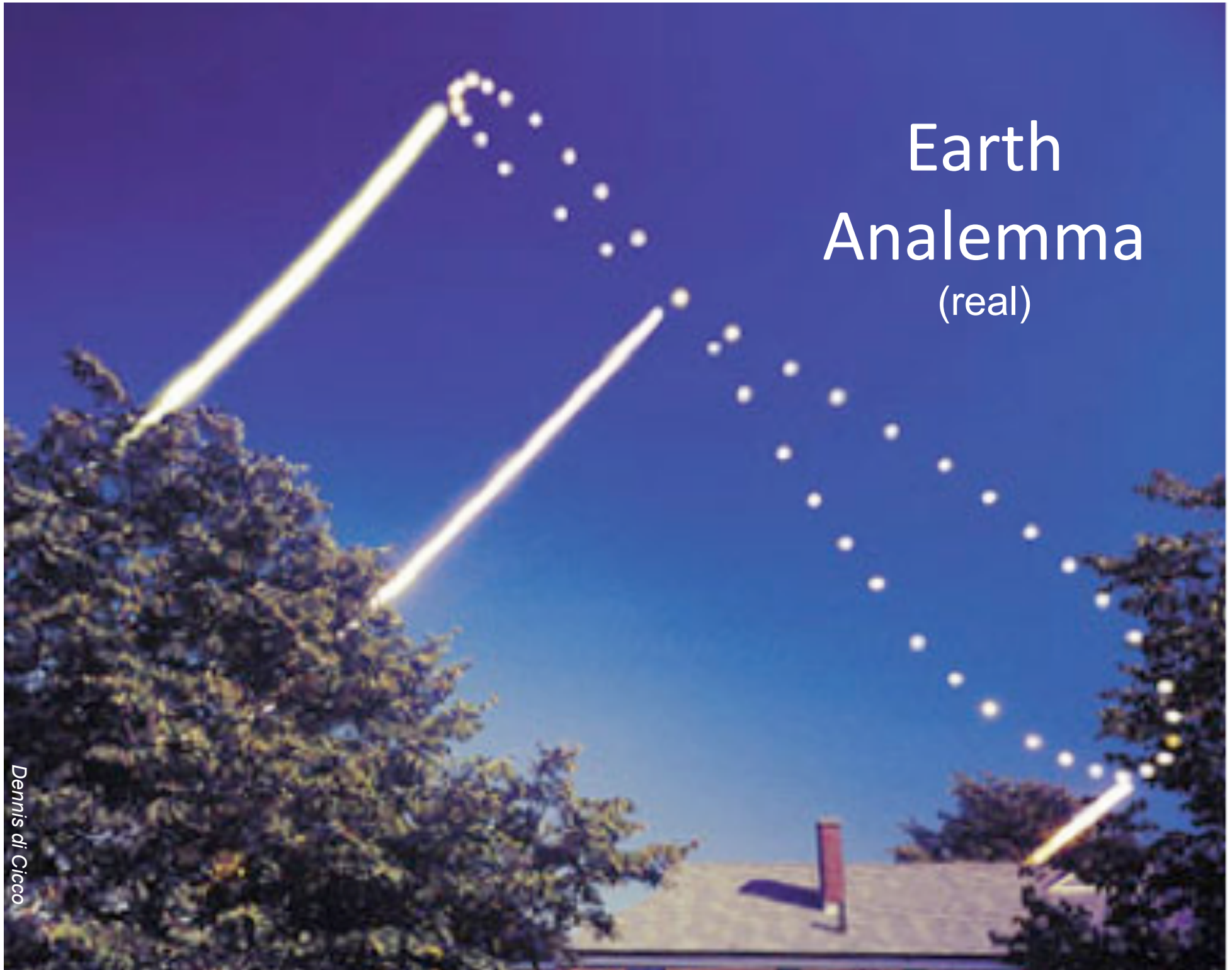
Sunclock (Equirectangular) Centered on 134.00°W

Martian Analemma

(simulated)



Earth Analemma (real)



II) To discover project requirements

- Understand scope and context
- Use case driven process
- Tools like UML/SysML
- Iterate throughout project

It is easier to change the specification to fit the program than vice versa.

– Alan Perlis (recipient of 1st Turing Award)

...but requirements are not specifications

What are the requirements for timekeeping?

The System of the World

- We are engaged in the same activity as
 - Ptolemy
 - Copernicus
 - Galileo
 - Tycho
 - Kepler
 - Newton
- Cosmology (in the original meaning) supplies the most basic engineering requirements

GPS World* offered 5 notional solutions

- Status quo
- Change the tolerance for UT1 – UTC
- Periodic insertion of leap seconds
- Redefine the second
- Discontinue leap seconds

**GPS and Leap Seconds: Time to Change?* – McCarthy & Klepczynski

<http://gauss.gge.unb.ca/papers.pdf/gpsworld.november99.pdf>

...and since then

- LEAPSECS mailing list discussions have elaborated and clarified all of these
- And the mailing list has been willing to explore completely different paradigms

The ITU deliberations

- Have only considered ceasing leap seconds
- As proposed, there is no coherent plan for the ramifications and new infrastructure
- Without a consensus on the problem to be solved, there can be no coherent solution
- Visibility into process is a key requirement

If leap seconds are discontinued

- The embargoed leap seconds continue to accrue
- These must be accommodated at some point
- A mechanism must exist for doing so
- This is the result of an unsatisfied requirement
- Leap seconds are a means to an end; they are a side show – not the main attraction
- UTC is a *solution*; the *problem* is civil timekeeping

Requirements have implications

- Too often engineering requirements are treated like preferences or whims
- Rather, a requirement is simply that – required
- Requirements are not specifications
- Requirements describe the problem space
- Specifications describe a proposed solution

III) To engage stakeholders

- Organize meetings
- Publish articles
- Engage in online discussions
- Seek out stakeholders on their own turf

User-centered design means working with your users all throughout the project.

– Donald Norman (~~author of *The Psychology of Everyday Things*~~)

Design

Who are the users of civil timekeeping?

Who are the stakeholders?

- Most broadly, everybody on Earth
- For the ITU, a narrow constituency
- Definitely astronomers – even if they don't want to think about it (AAS and IAU punted on the issue)
- Not just the “precision timekeeping community”
- Many communities remain unaware of this issue

IV) Time is in danger

- Atomic time and Time-of-day are different things
- If we pretend otherwise, there are ramifications
- Consensus should be sought beforehand
- Any proposal should include a mitigation plan

Ask yourself, what is this thing in itself, by its own special constitution? What is it in substance, and in form, and in matter? What is its function in the world? For how long does it subsist?

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Questions

- What is civil timekeeping?
- Who are the users of civil timekeeping?
- What are the requirements for timekeeping?


Answers

- Systems engineering is the way to:
 - Find the answers
 - Communicate effectively with stakeholders
 - Discover requirements
 - Design a solution
 - Implement the design
 - Operate and maintain the result
 - and do it all as *quickly* as possible

Vocabulary of engineering

- *Problem statement*: civil timekeeping
- *Proposed solution*: UTC (+ NTP, etc)
- *Feature of solution*: intercalary steps

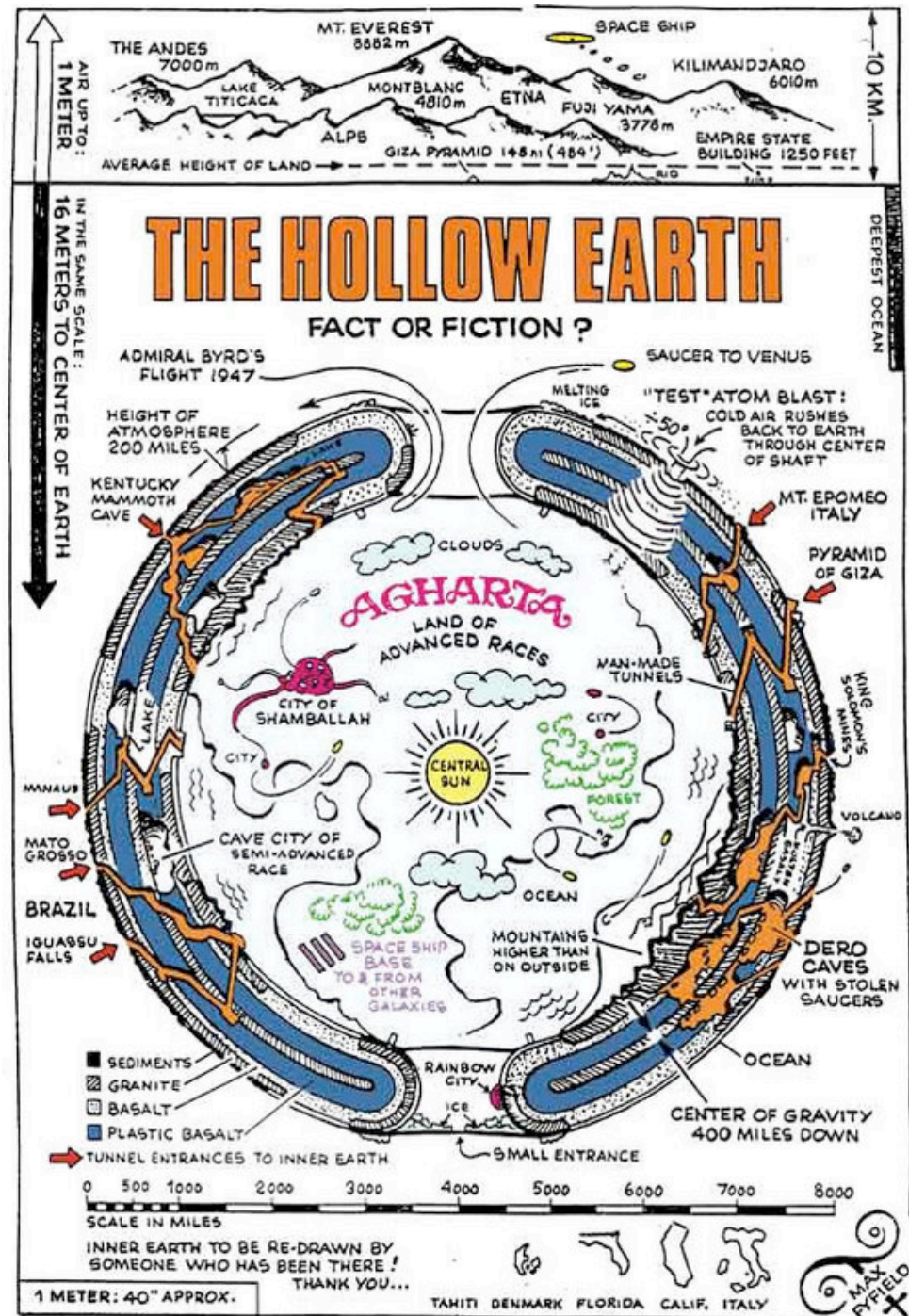
In particular:

- *Requirement*: civil time  mean solar time
- *Specification*: leap seconds

Questions for the next two days

- What is civil timekeeping?
- Who are the users of civil timekeeping?
- What are the requirements for timekeeping?

- Schematic representation





Symmes Hole

“Above me hung another world.”

“As I watched it, I saw that it was revolving upon an axis that lay parallel to the surface of Pellucidar, so that during each revolution its entire surface was once exposed to the world below and once bathed in the heat of the great sun above. **The little world had that which Pellucidar could not have—a day and night, and—greatest of boons to one outer-earthly born—time.**

In short, by comparison

- Simply ceasing leap seconds cannot be a coherent systems engineering model
- It does not map onto a physical model of even a science fiction reality

Systems Engineering Plan

	Name	Order in which the documents are started	Order in which the documents are finished
Doc. 1	Problem Situation	1	8
Doc. 2	Customer Requirements	5	2
Doc. 3	Derived Requirements	6	4
Doc. 4	System Validation	7	5
Doc. 5	Concept Exploration	3	3
Doc. 6	Use Case Model	4	1
Doc. 7	Design Model	8	6
Doc. 8	Mappings and Management (schedules)	2	7

Other processes are similar

- **S**tate the problem
- Investigate alternatives
- **M**odel the system
- Integrate interfaces
- **L**aunch the project
- **A**ssess performance
- **R**e-evaluate your solution

This is a Technical Issue