Satellitennavigation— wie funktionierts?

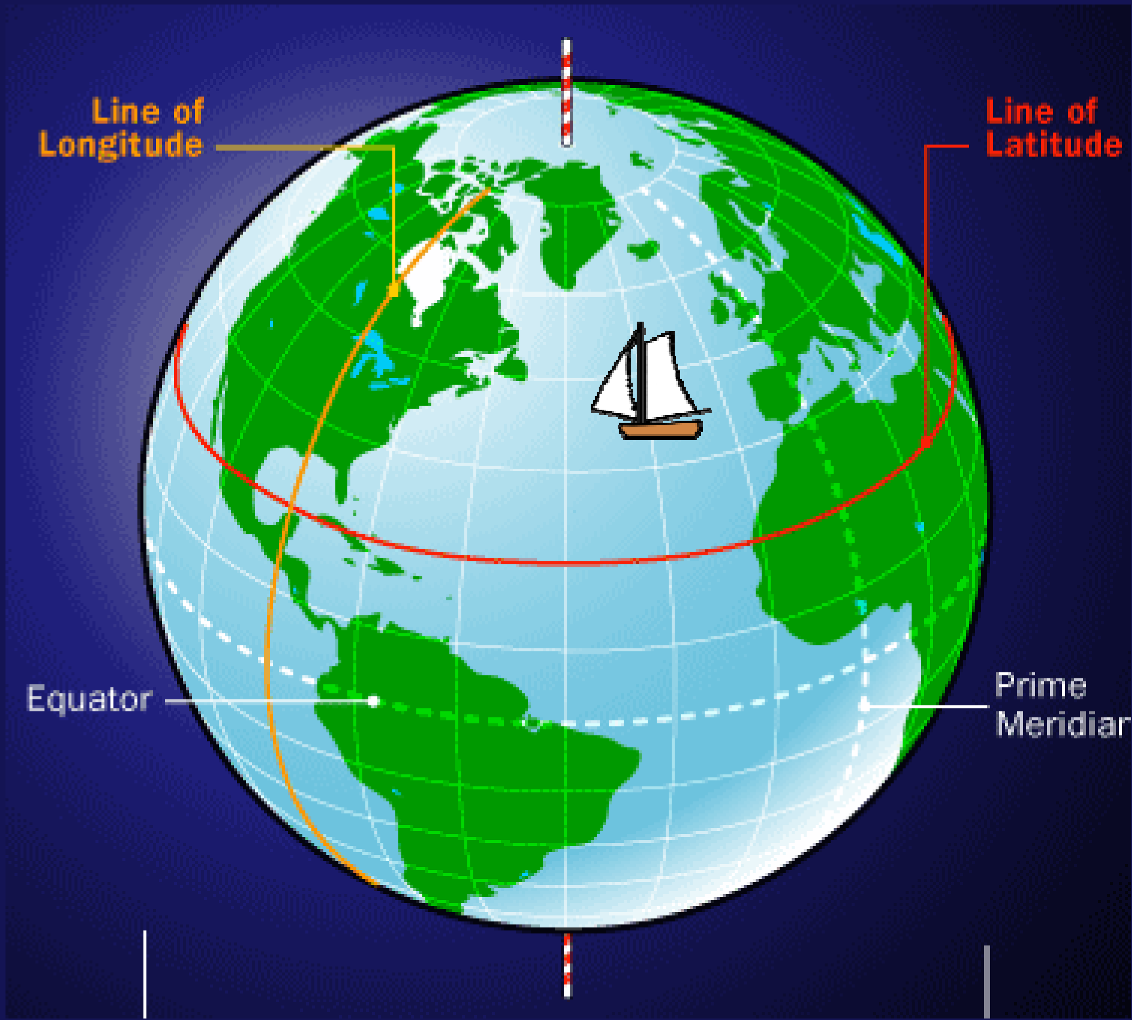
TecDay@KSH

Heinz Mathis

4. Mai 2010

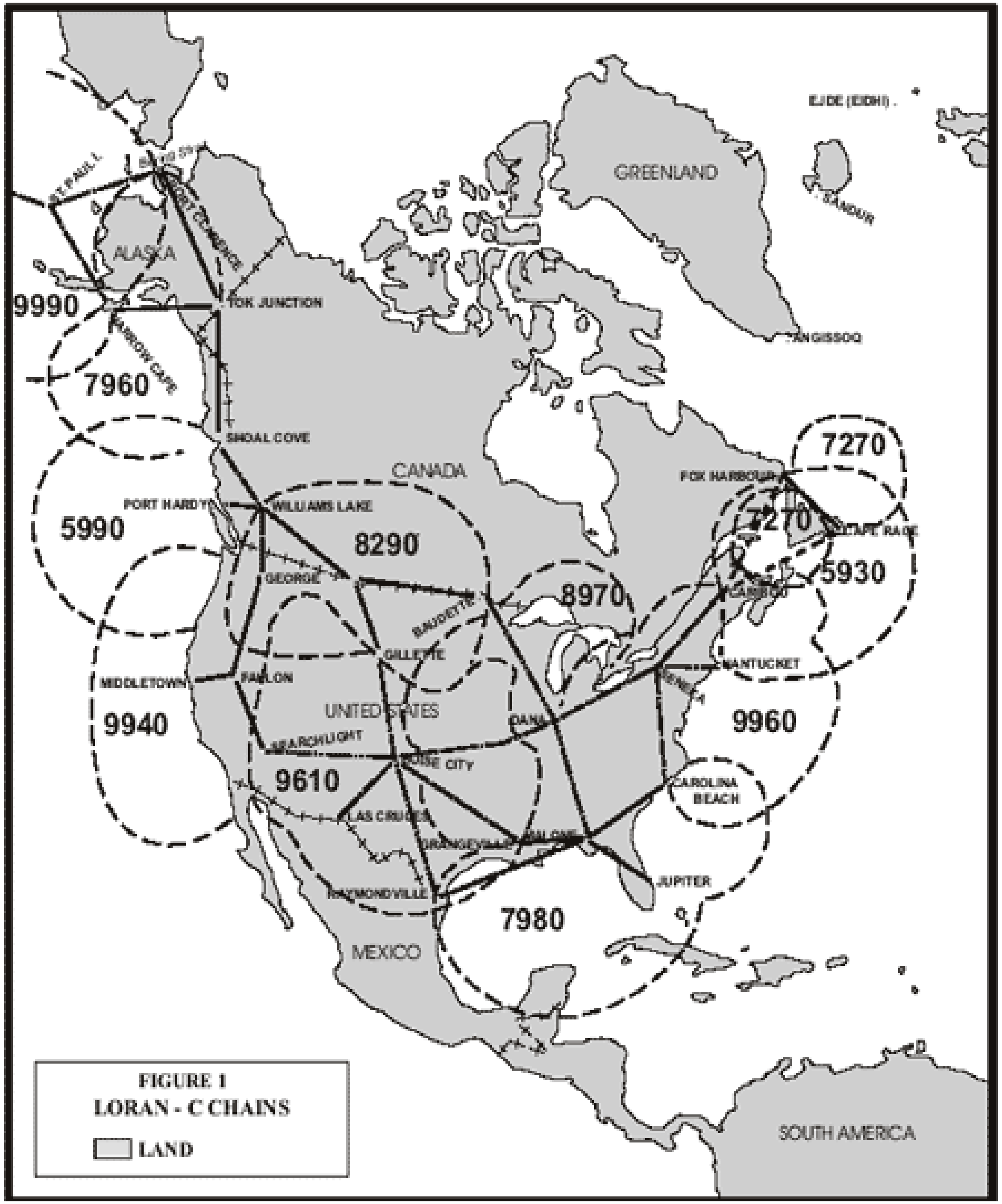

86° NB 65° WL
AN ALLE:
EINLADUNG ZUM
FRÜHSTÜCK!
NORDPOL
EXPEDITION
86° NB 65° WL
AN ALLE:
HILFE!

Latitude and Longitude




DENT

LORAN, starting at WWII

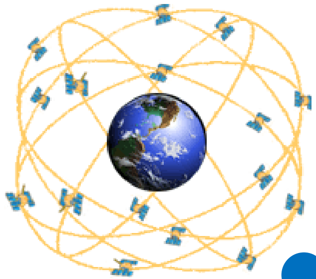


Navigation **S**ystem with **T**iming **a**nd **R**anging

Global **P**ositioning **S**ystem

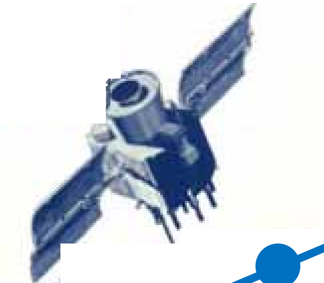
History of GPS

time



2000: SA off

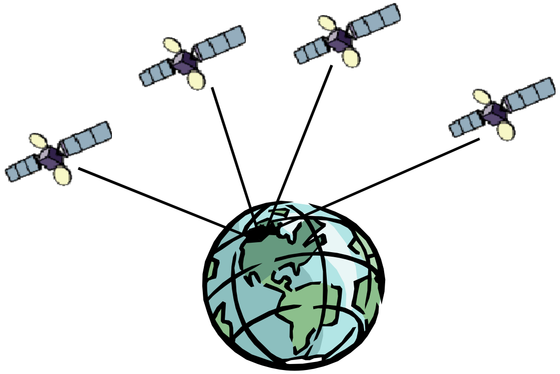
1993: fully operational
with 24 SVs



1978: launch of 1st GPS SV

1973: start of the NAVSTAR GPS project

Initial goals of GPS



3D positioning on earth and in proximity (possibly moving)

speed of objects

time information

unlimited #users

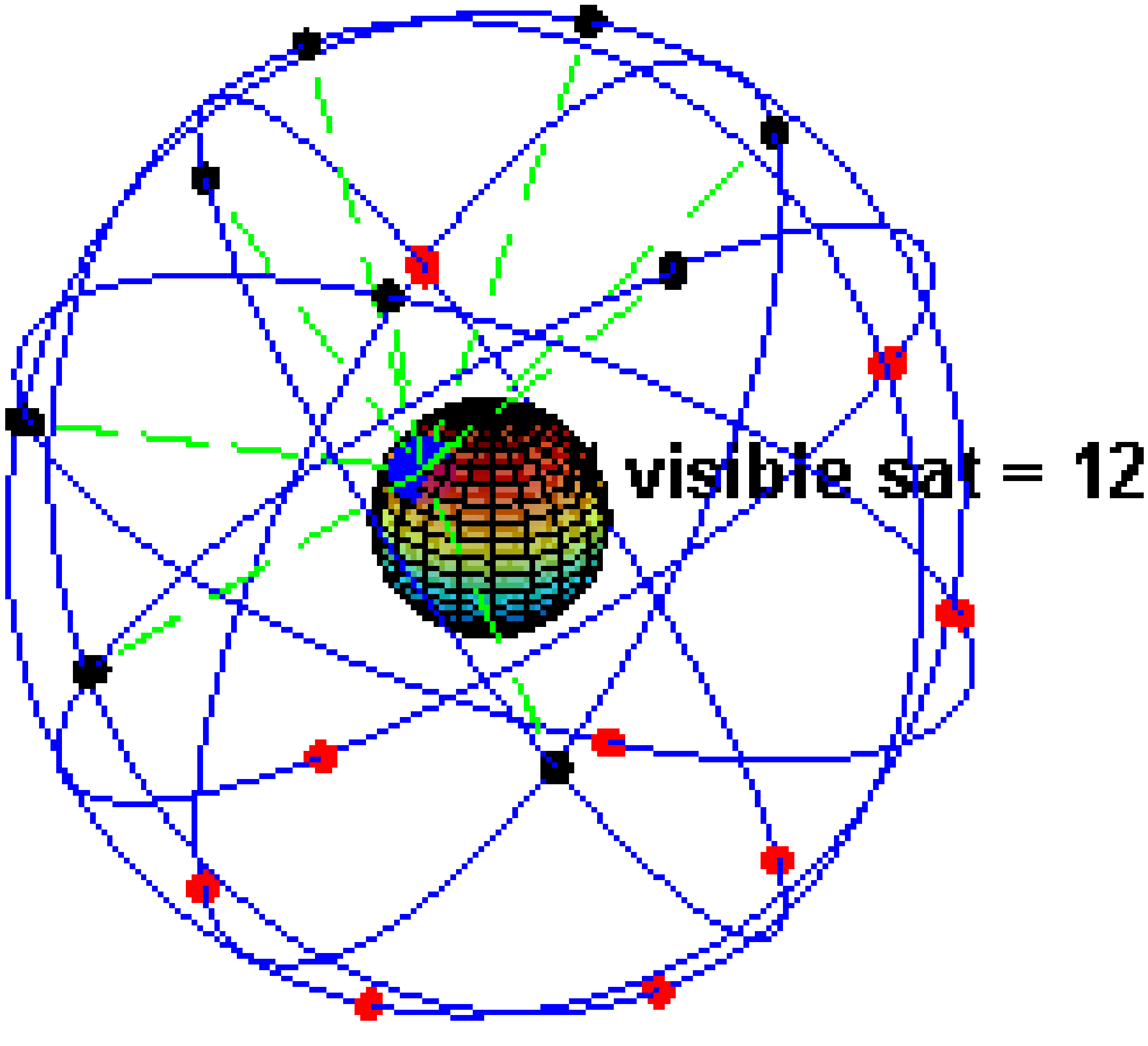
independent of weather

immunity to jamming

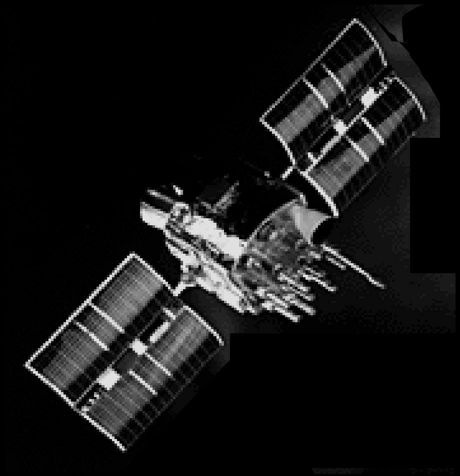
System overview

Satellite constellation

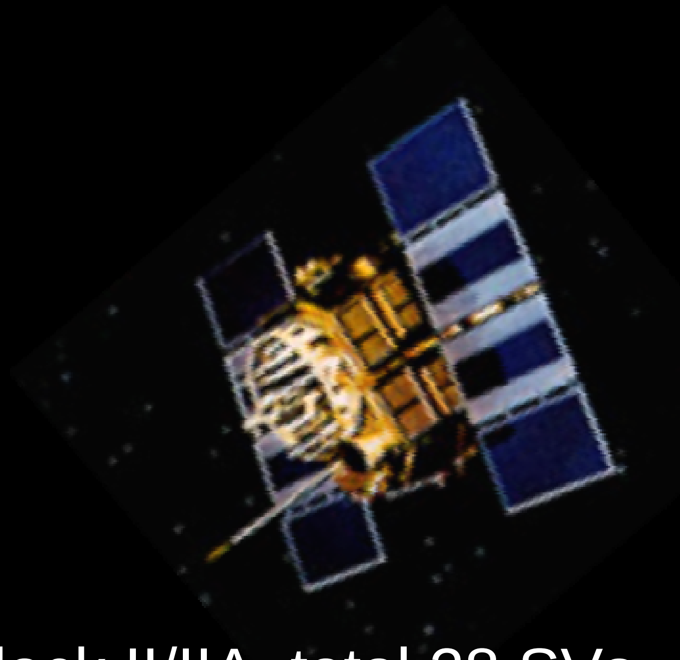
MEO SVs



Satellite types in GPS

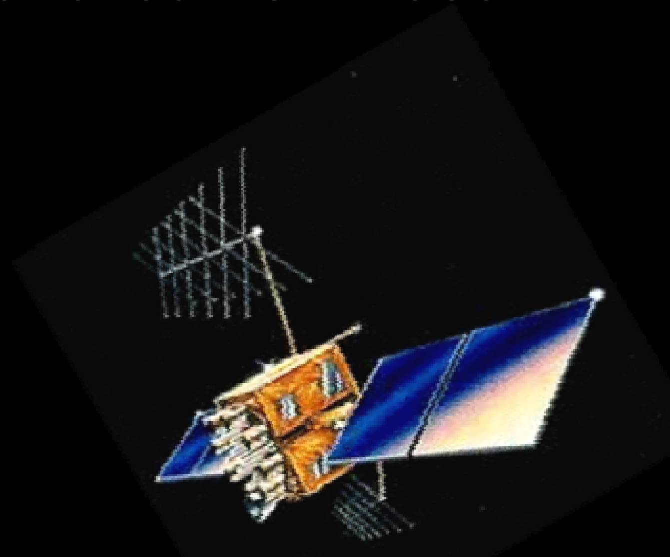


Block I, total 11 SVs
launched from 1978



Block II/IIA, total 28 SVs
launched from 1989

Block IIR/IIR-M, total 15 SVs
launched from 1997

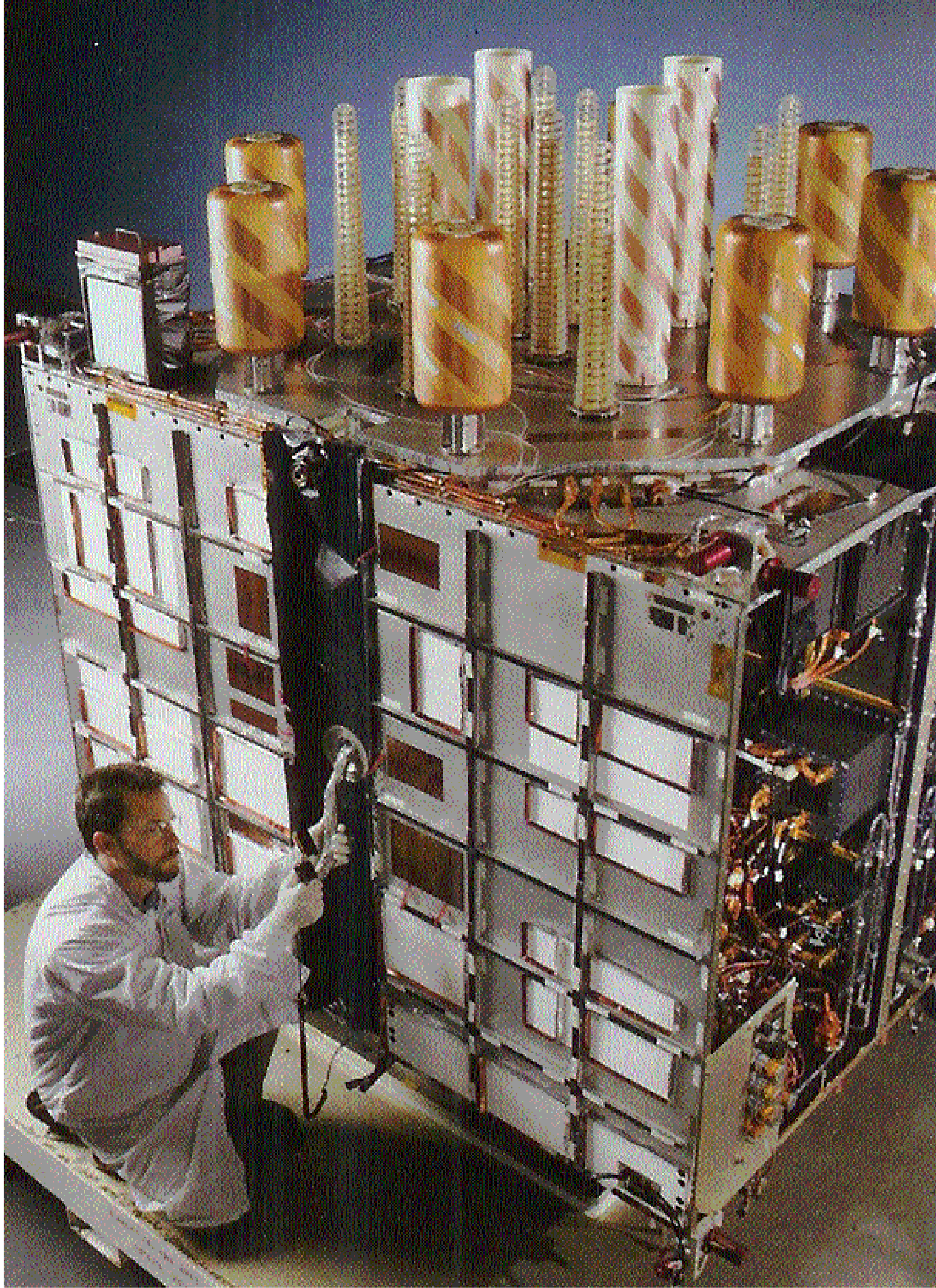


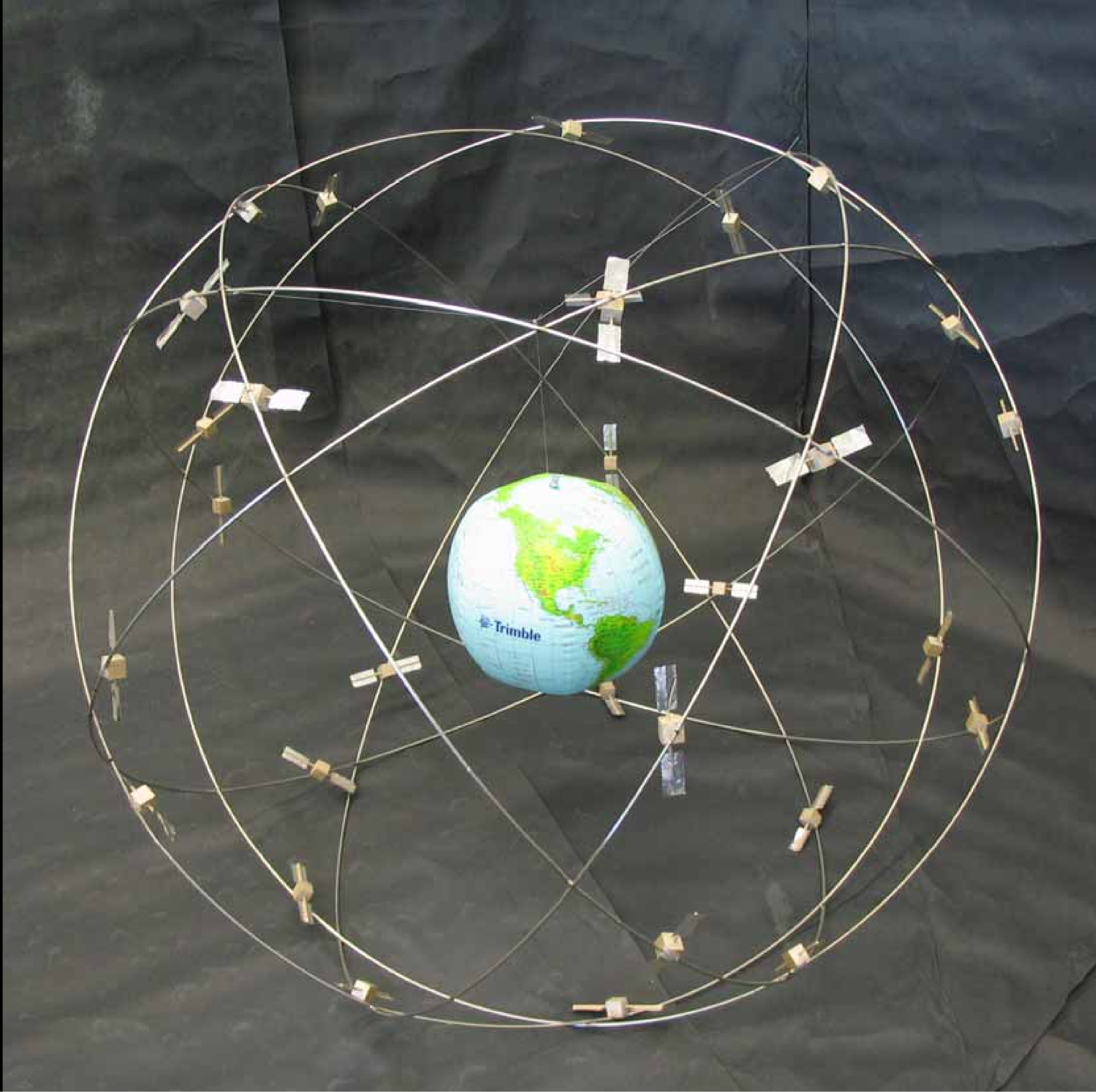
Block IIF, total 12 SVs
launched from 2005

SV
space vehicle

GPS-2RM (launched Sept 2006)

Weight: 845 kg

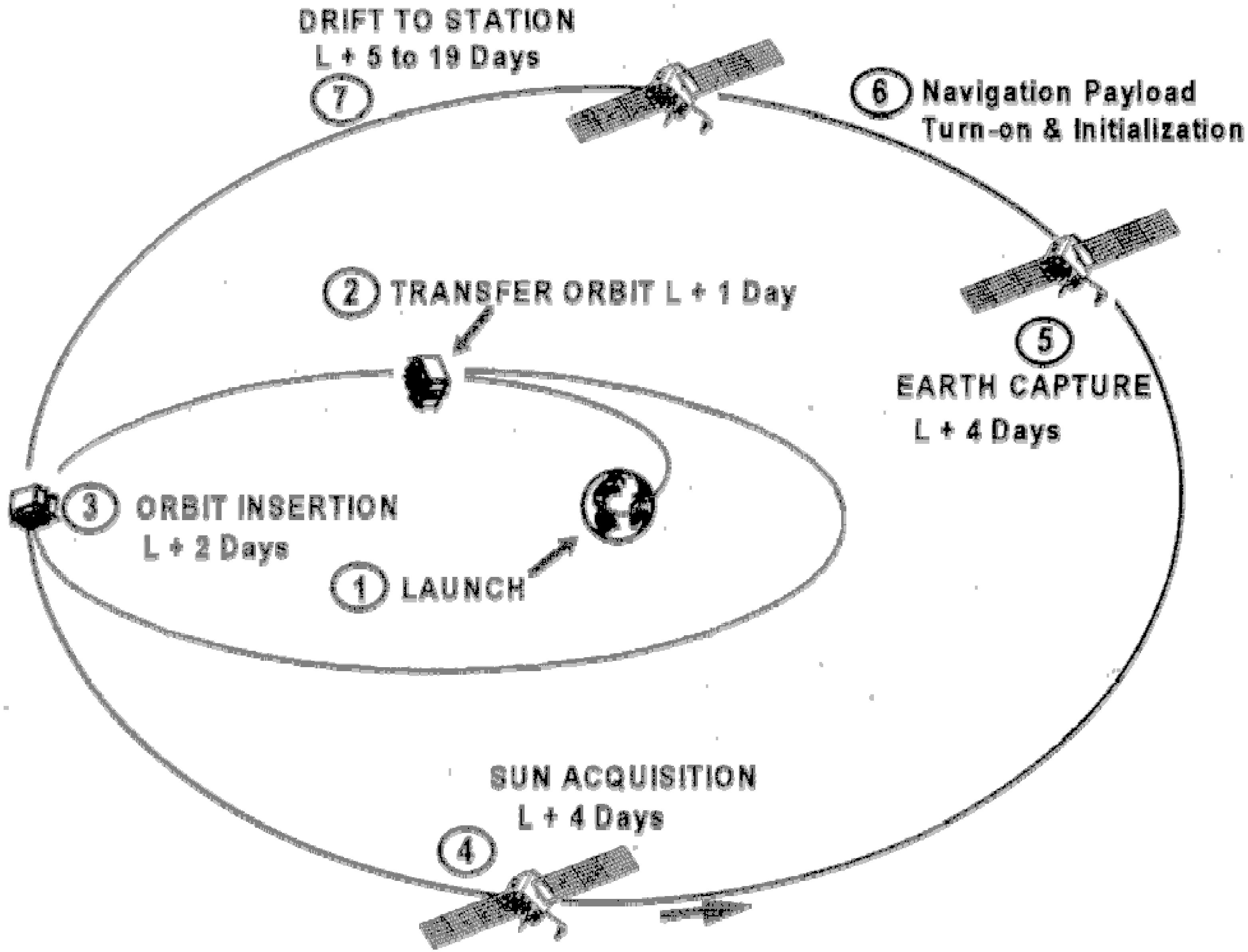



Trimble

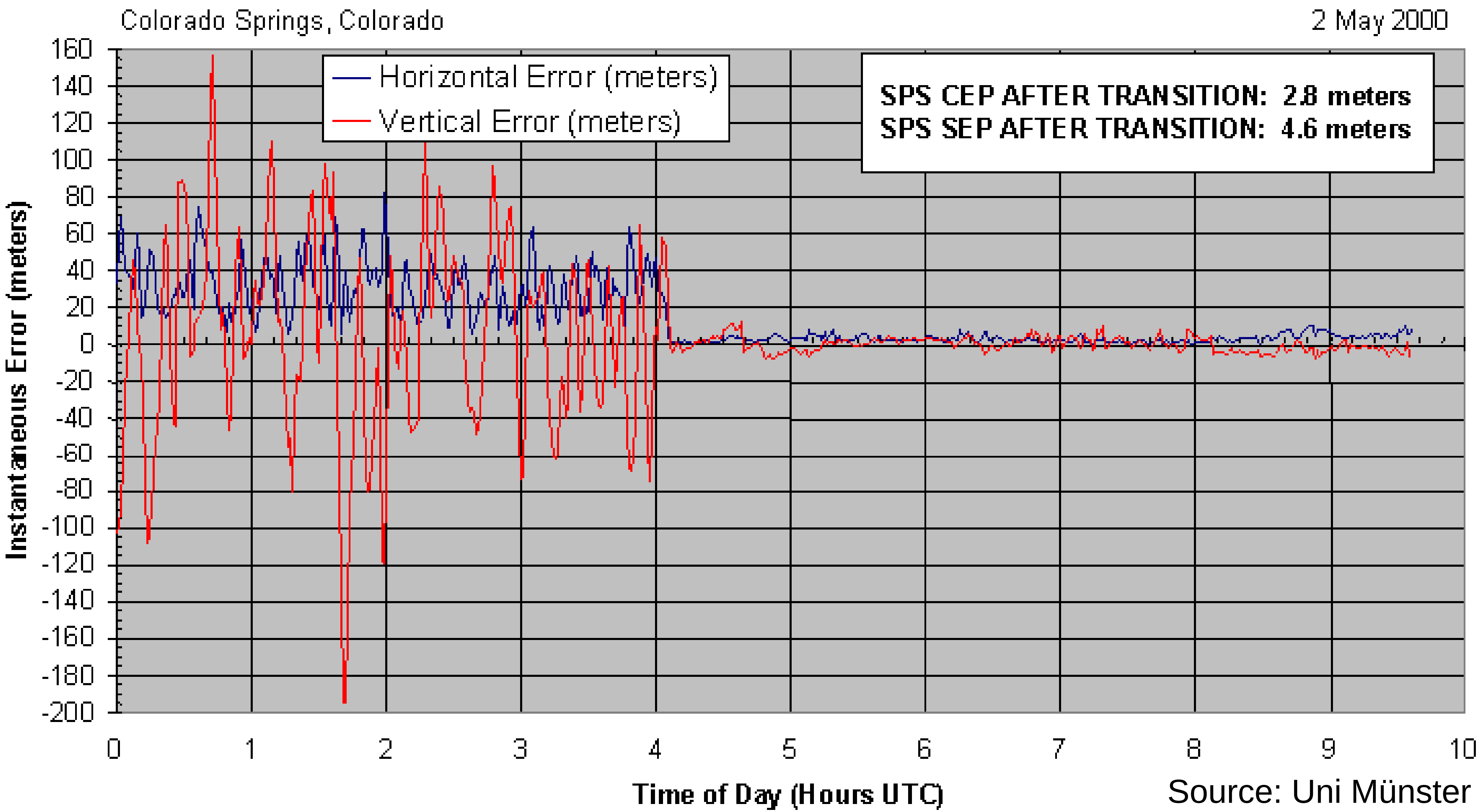
June 23, 2004:

GPS IIR-12

SV launch process

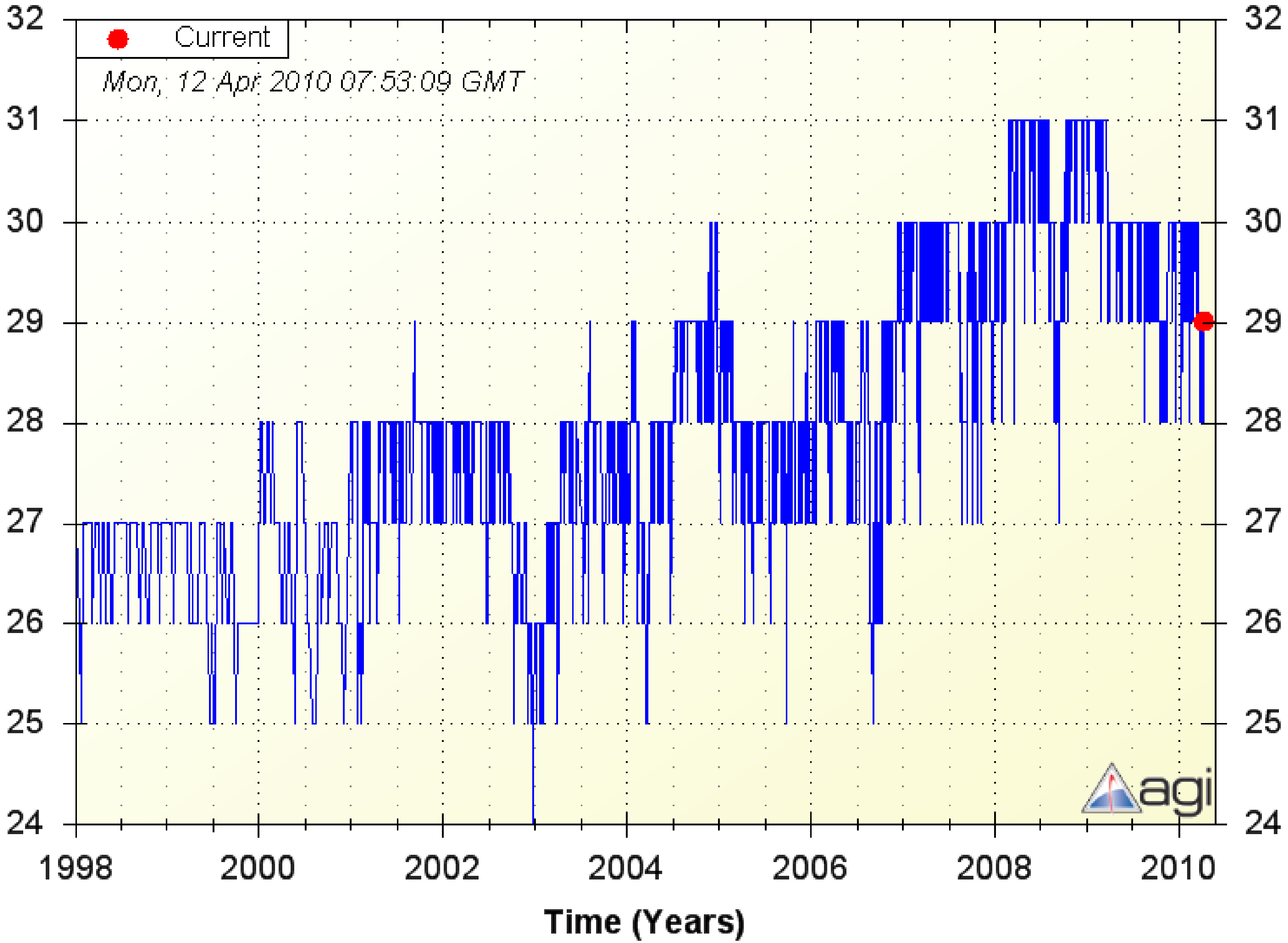


SA Transition -- 2 May 2000

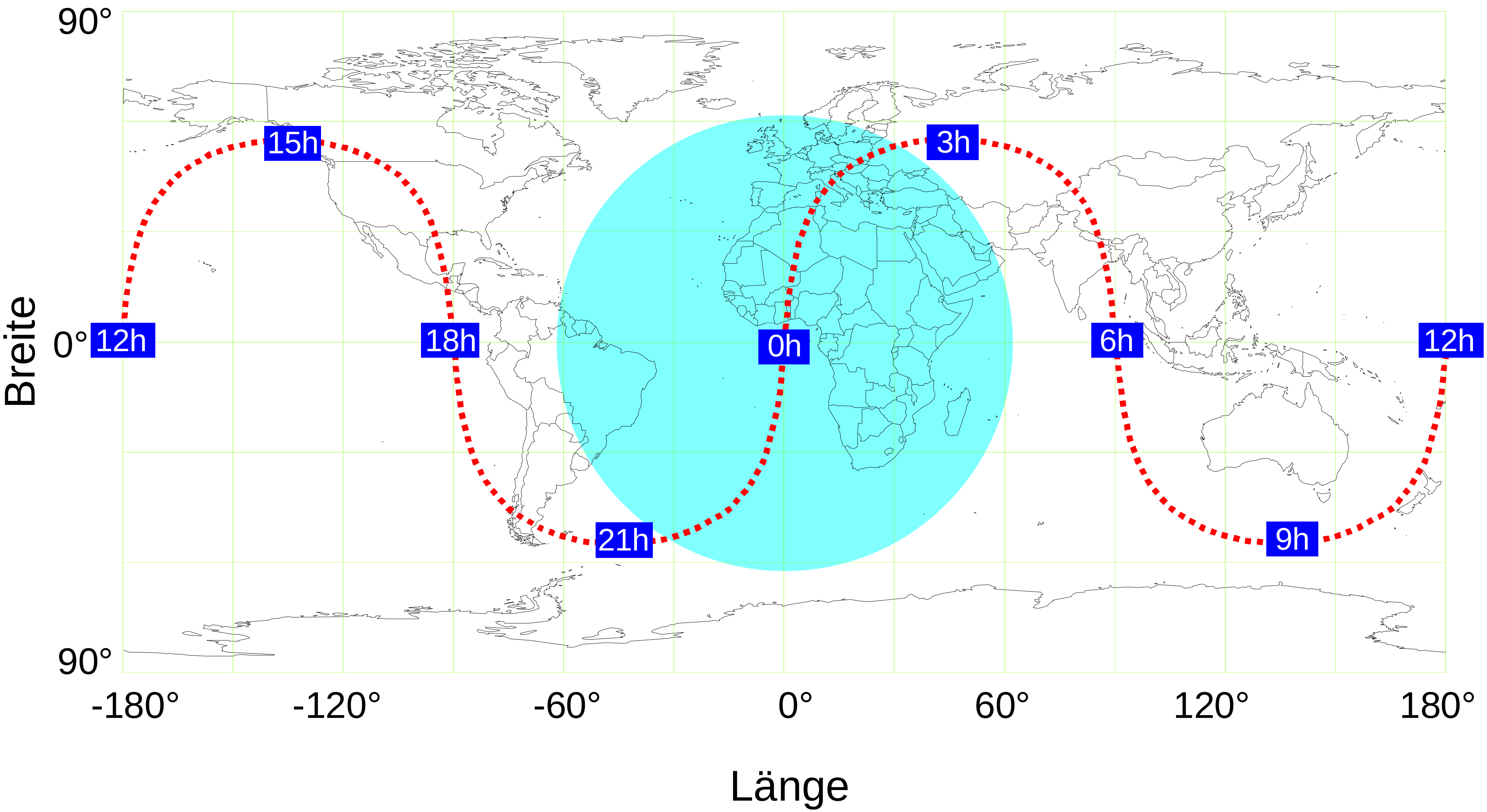


Source: Uni Münster

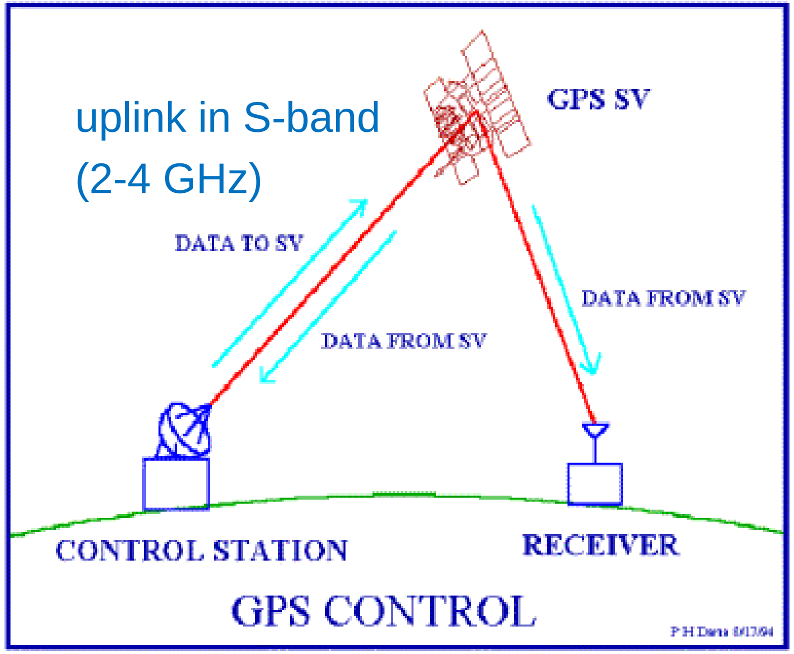
29 usable GPS SVs as of April 12, 2010

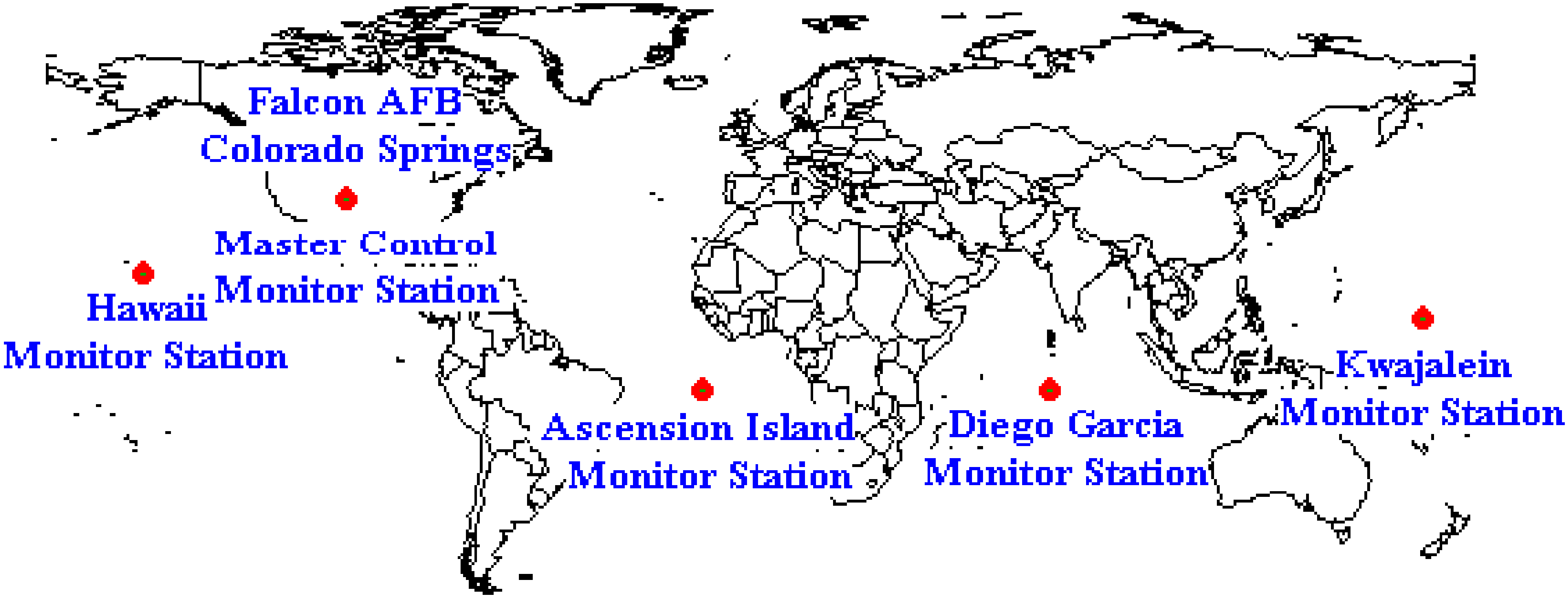


Trajectories

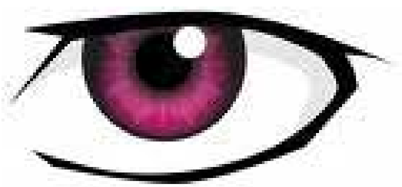


Master Control & Monitor Station Network



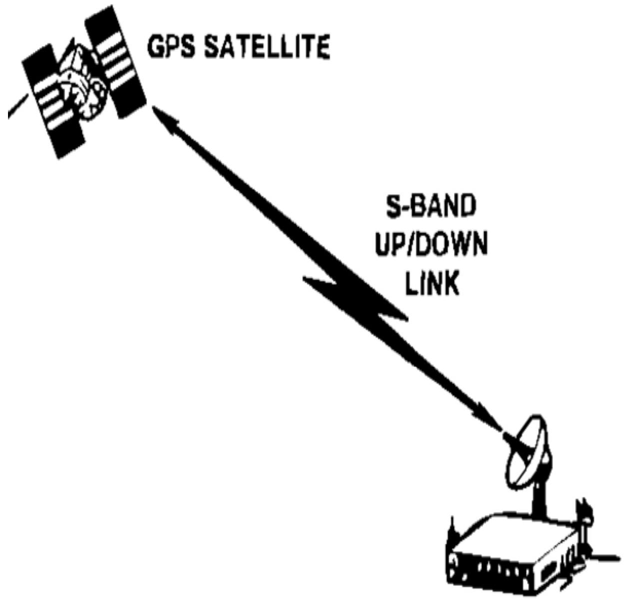


Control segment tasks



observation of
SV movement

computation of
ephemerides



transmission of
navigation data to SV

time synchronization
of SVs

surveillance of SV
clocks

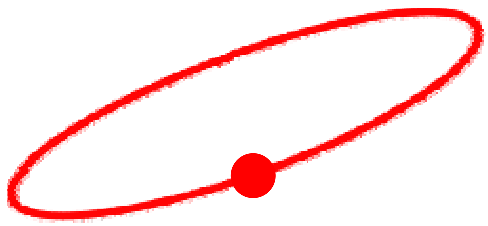

The user segment is
the least specified
GPS 12

Was wird übertragen?

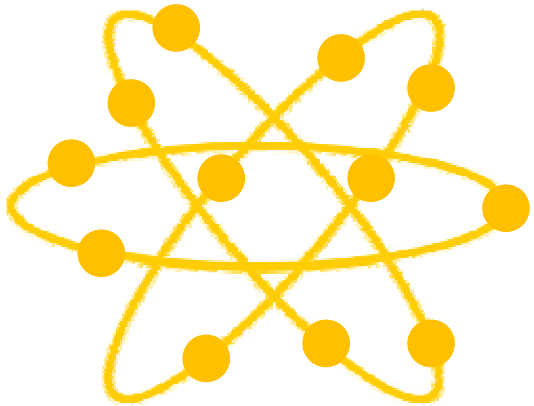
- **50 bit/s Datenstrom**
- **30 sek Übertragungszeit für einen Satz**
- **12.5 min Übertragungszeit für alle Daten**
- **HF-Signal liegt bei 1.57542 GHz**

Data transmitted from SV

time and synch signals

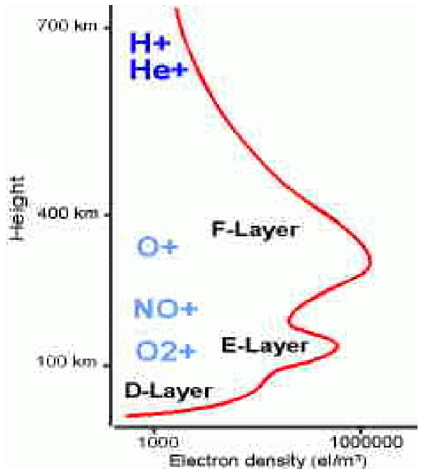


ephemerides

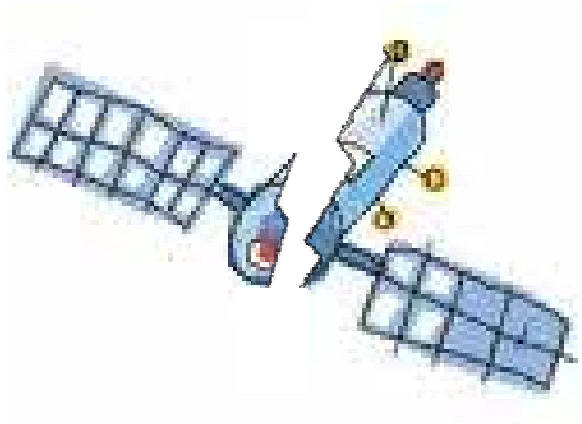


almanach

time correction signals



ionospheric data



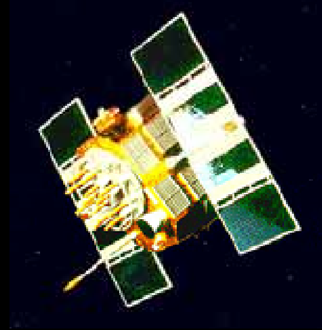
health information

Ein GPS-Modul (kompletter Empfänger) ist klein!

16 x 12.2 x 2.4 mm

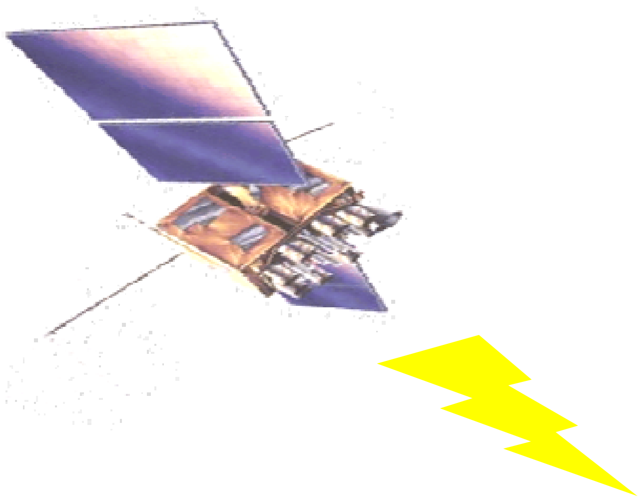
Was brauchts noch?

Sendeleistung: 22 W

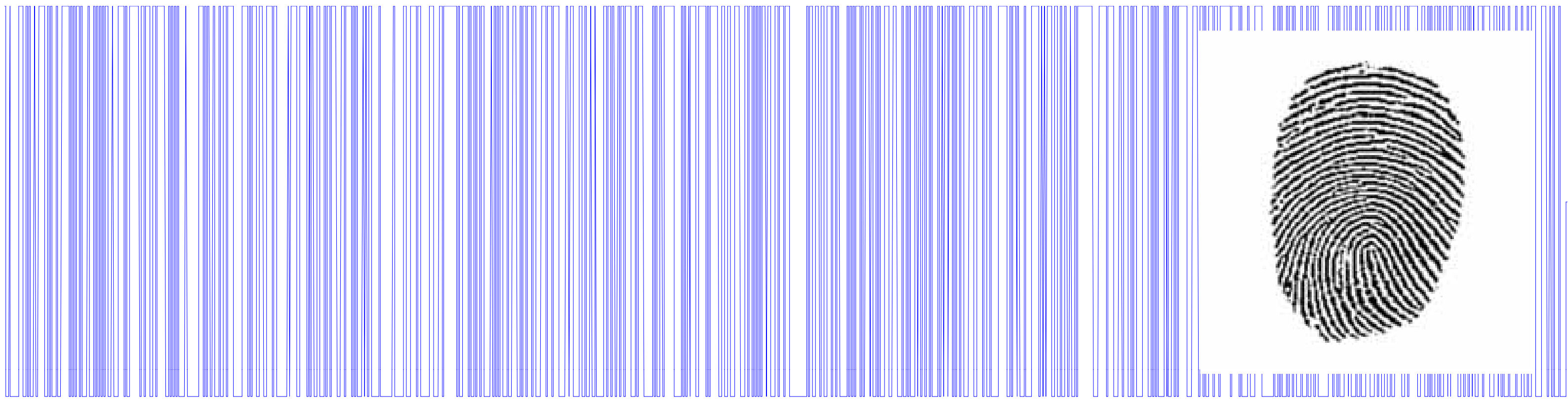


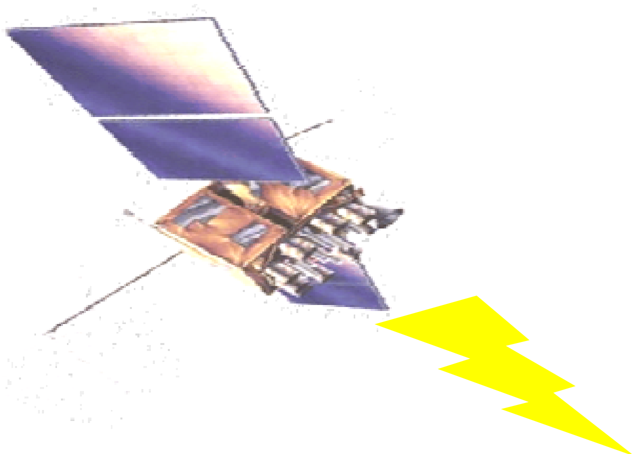
Empfangene Leistung: 10^{-16} W

SV signals are like fingerprints

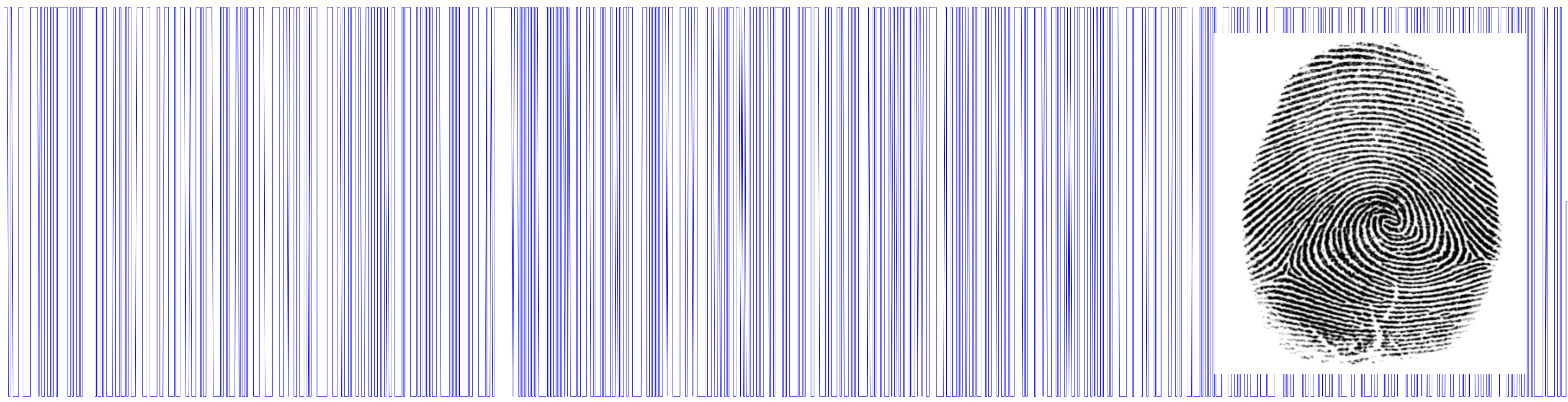


satellite 1

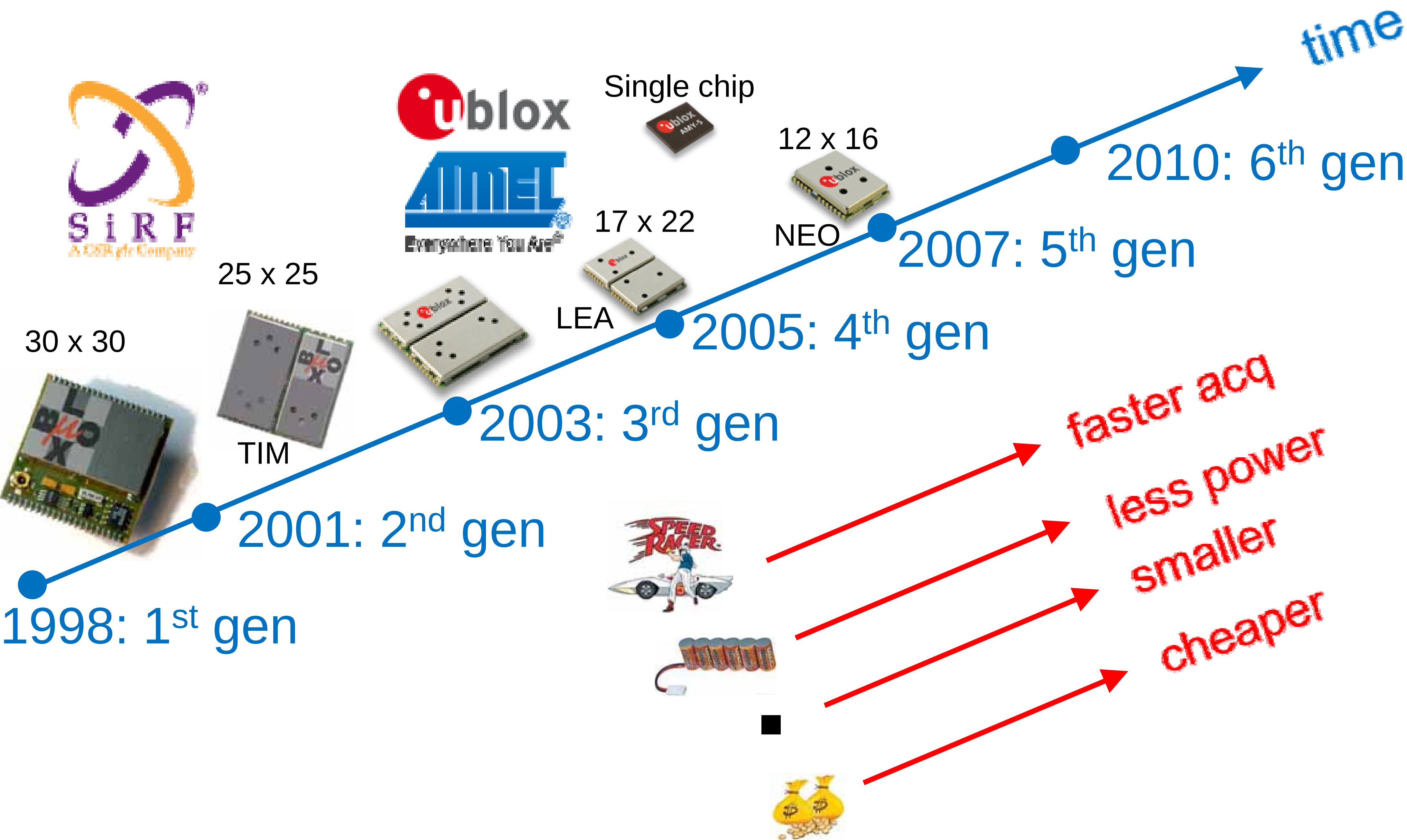




satellite 2



GPS receiver generations



Albert Einstein

born 1879

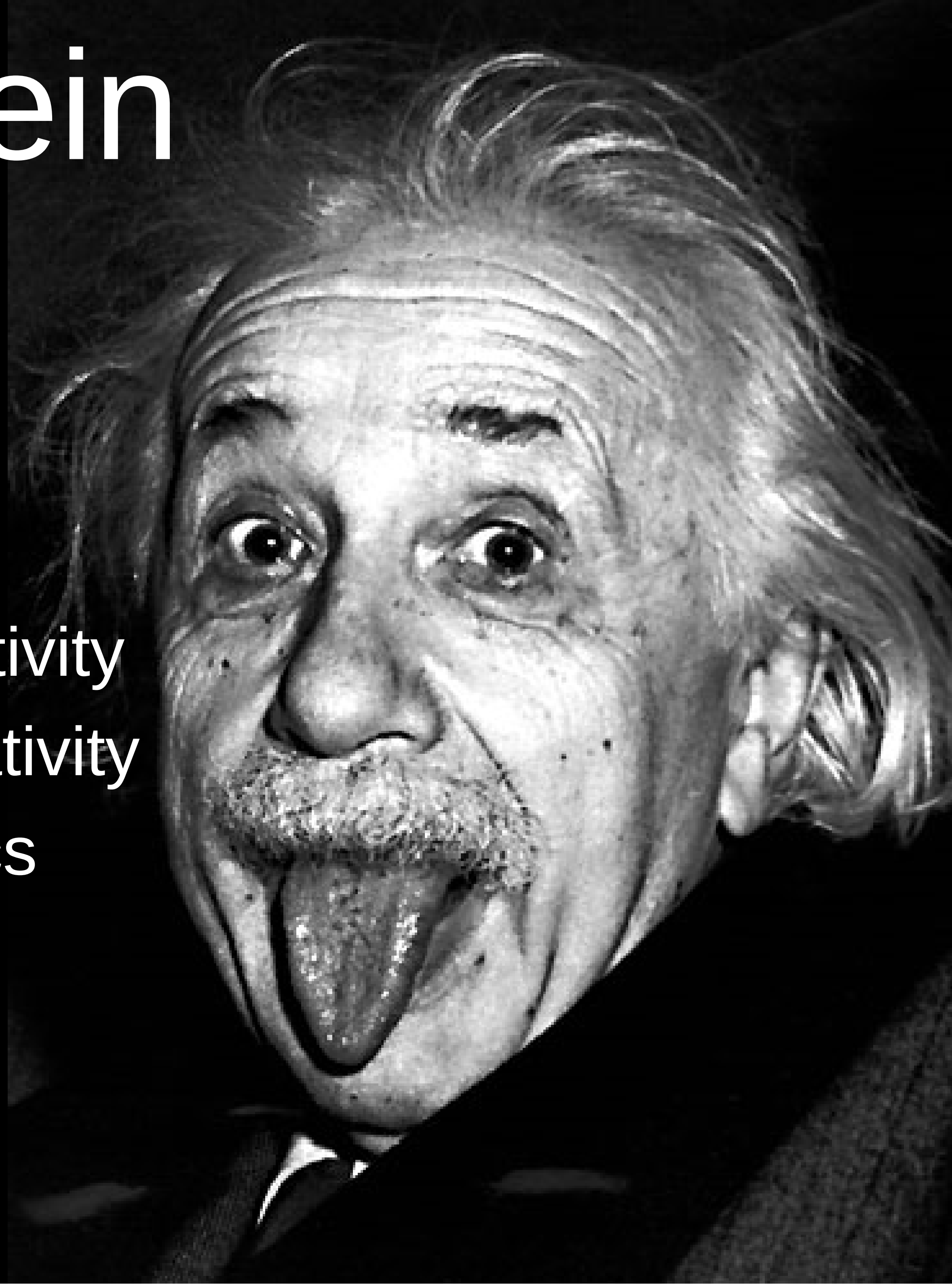
1905 photoelectric effect

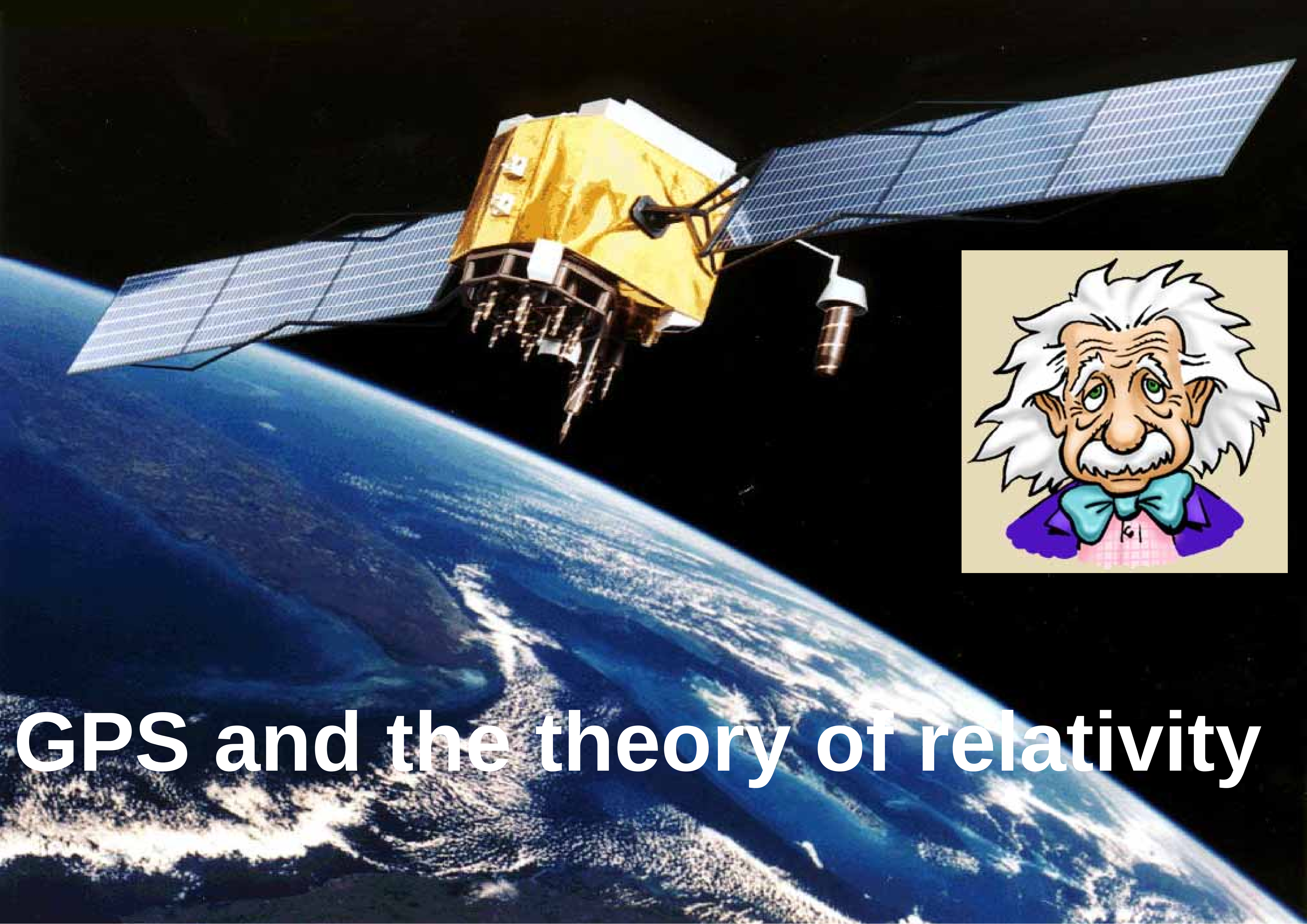
1905 special theory of relativity

1915 general theory of relativity

1921 Nobel Prize in Physics

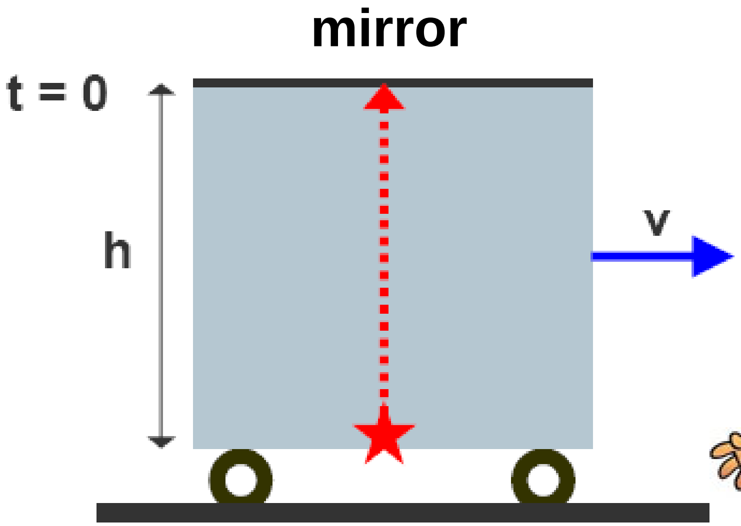
† 1955





GPS and the theory of relativity

Special relativity: problem formulation:



moving observer:

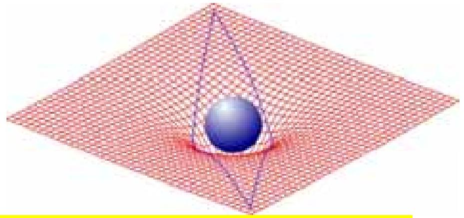
the light covers a distance of

$s = 2h$.

Hence,

$t = s/c = 2h/c$.

Relativistic effects



special relativity

v=3880m/s

SV clock lags by 7.2us per day!

general relativity

h=26'000km

SV clock leads by 45.9us per day!

net effect

SV clock leads by 38.7us per day!

→SV covers 15cm

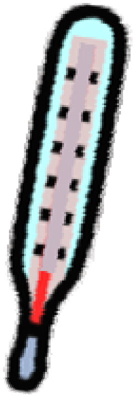
→ earth rotates 17mm (equator)

Solution:

reference frequency =

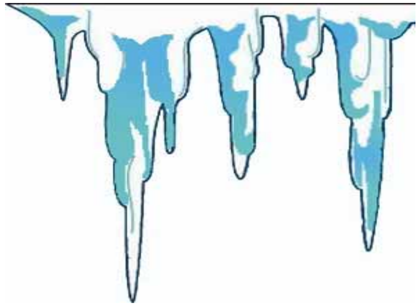
10.229999995433 MHz instead of 10.23 MHz

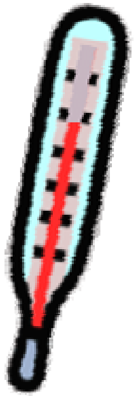
Acquisition modes



cold start:

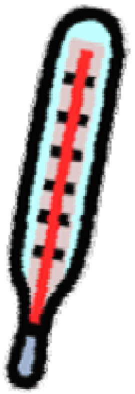
nothing is known





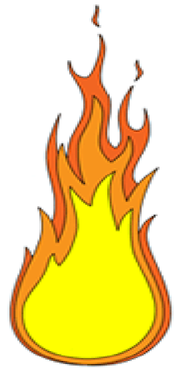
warm start:

restart outside 2h



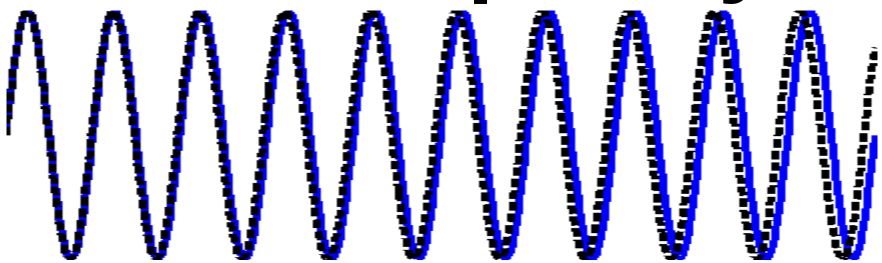
hot start:

immediate restart (within 2h)

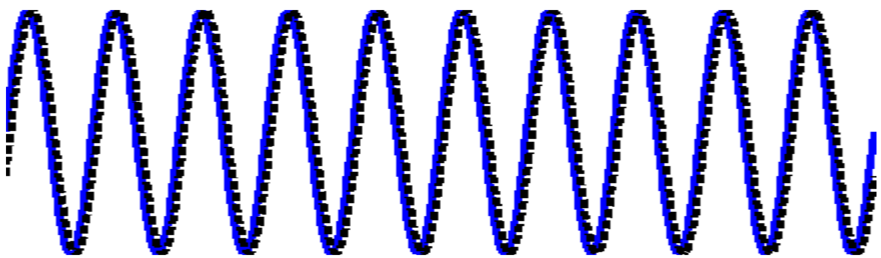


Tracking (never let go)

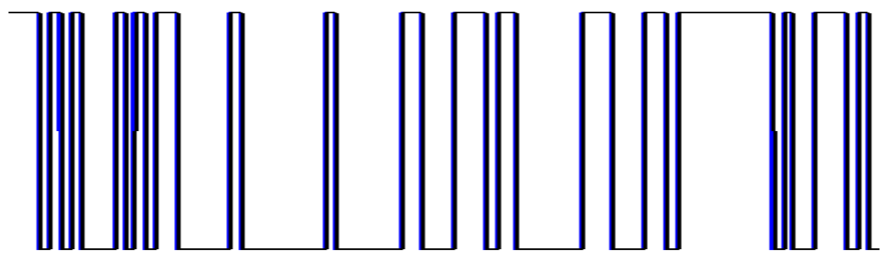
carrier frequency



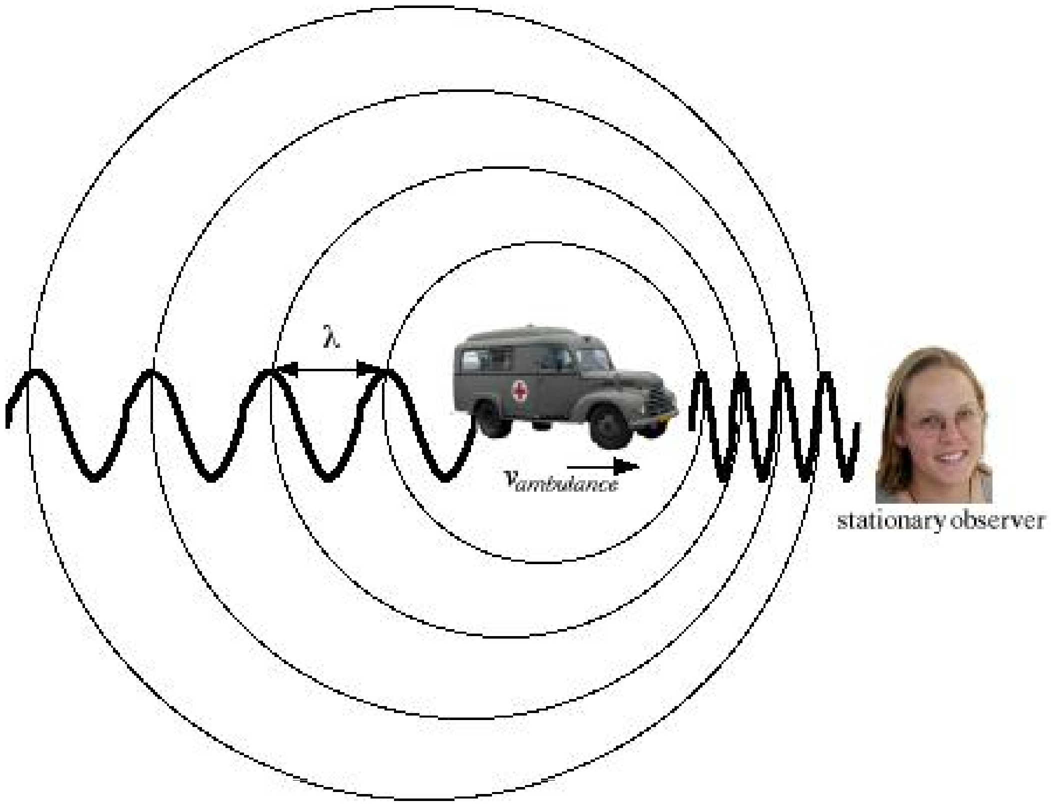
carrier phase



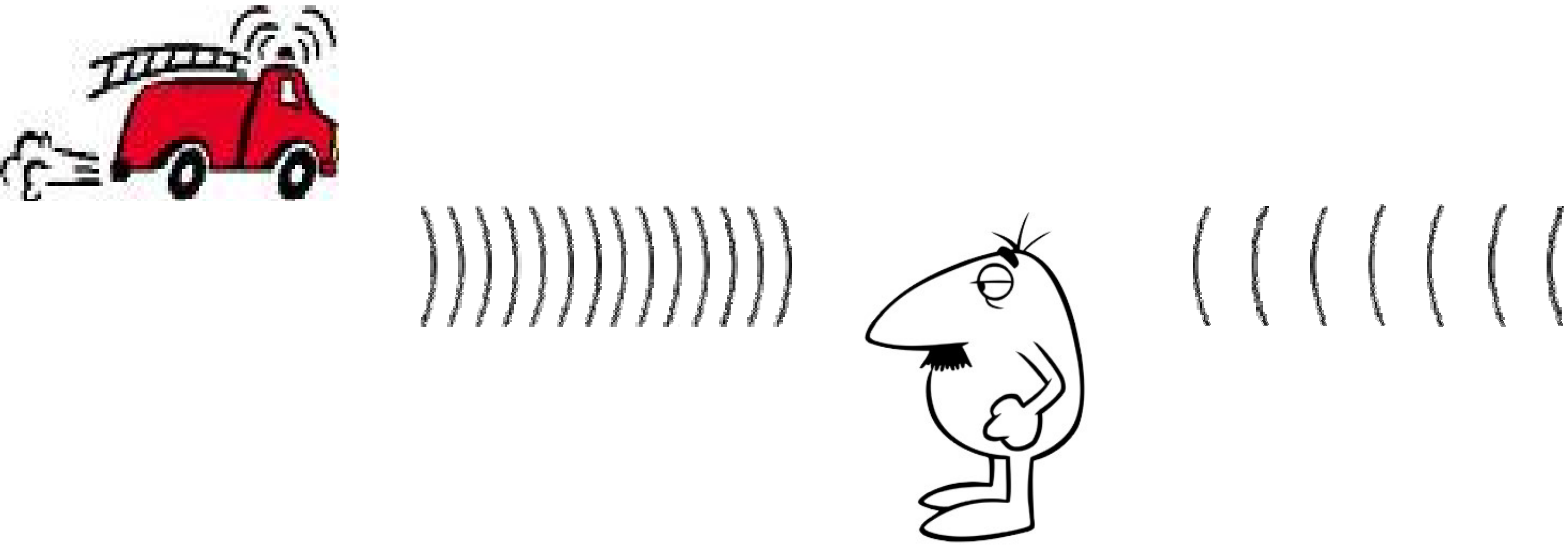
code phase

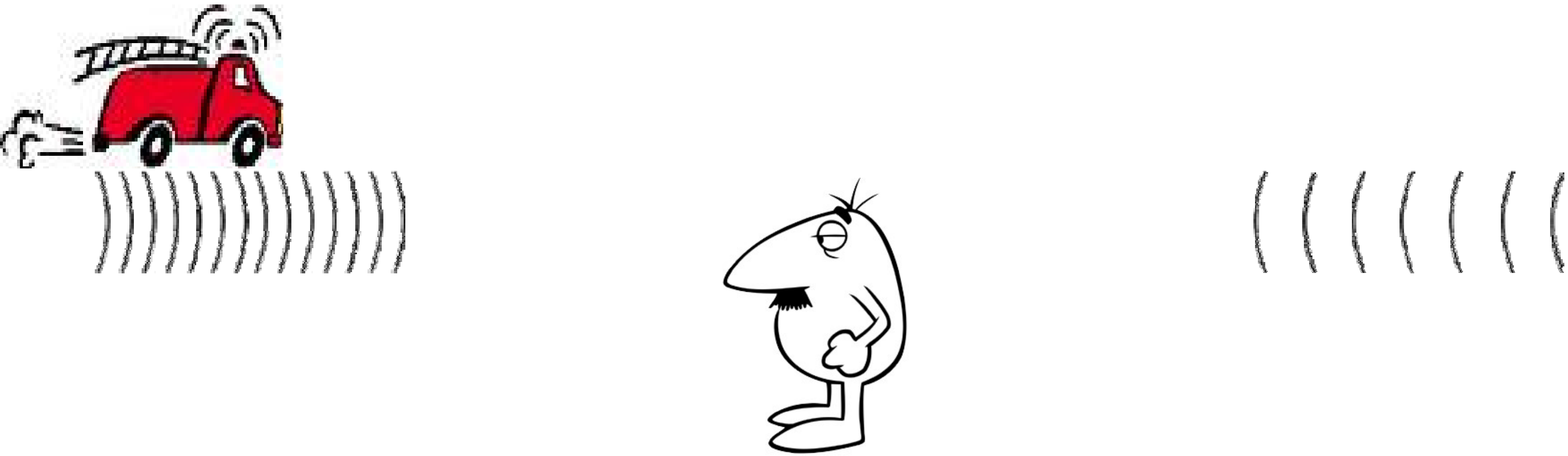


Doppler effect



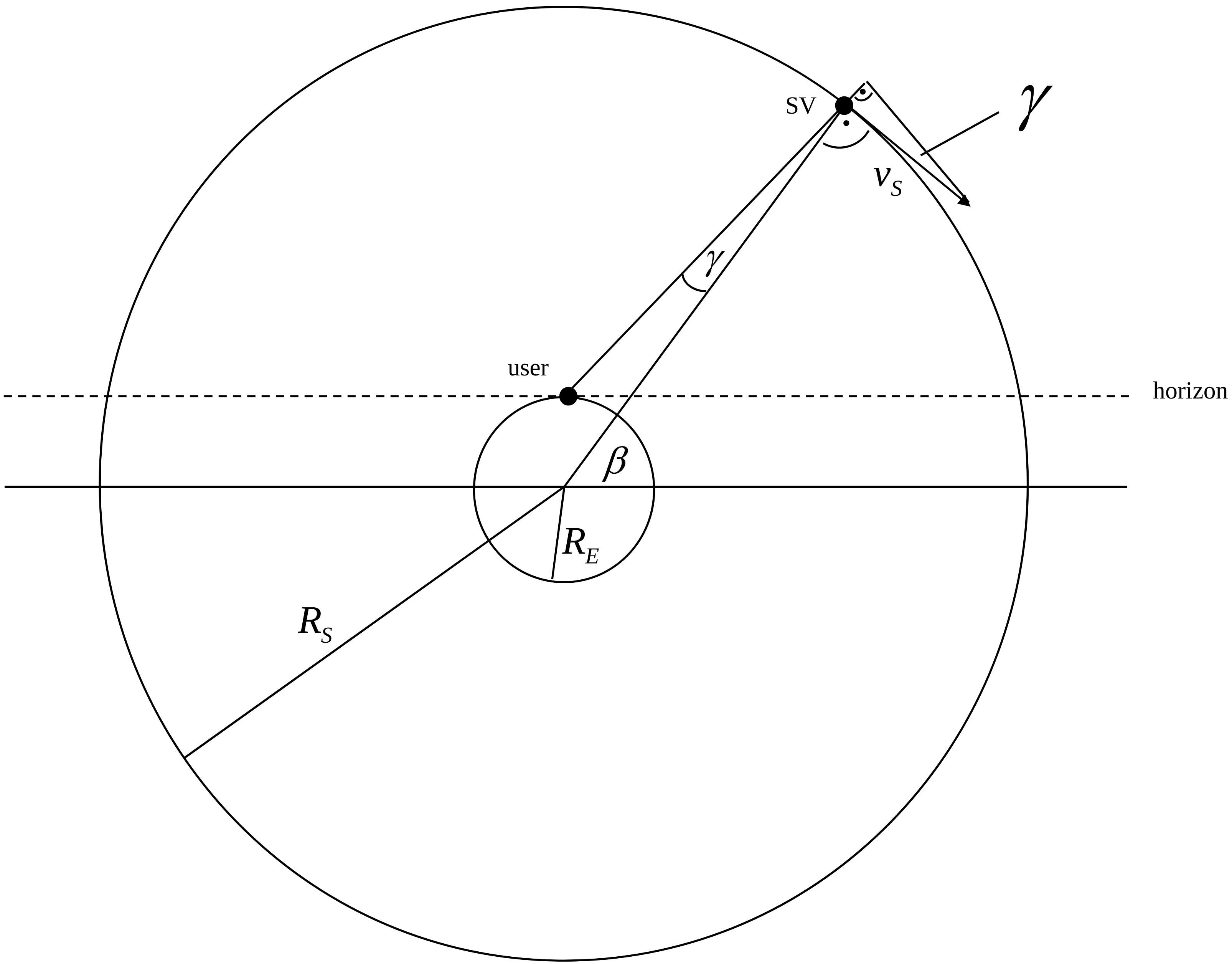
Christian Andreas Doppler (1803 – 1853)





Doppler effect

$$f = \frac{v}{c} f_{\mathrm{RF}}$$

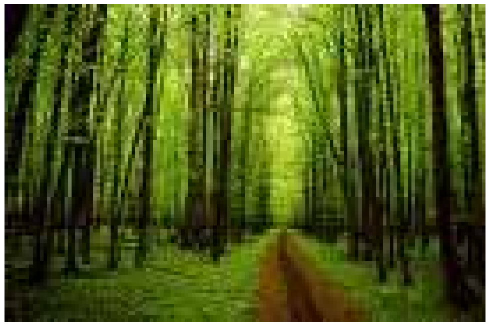


Performance depends on ...

global location

local location

dynamic movements



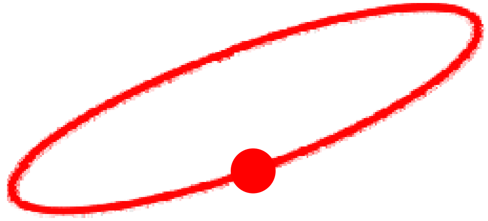
quality of signal

complexity of receiver

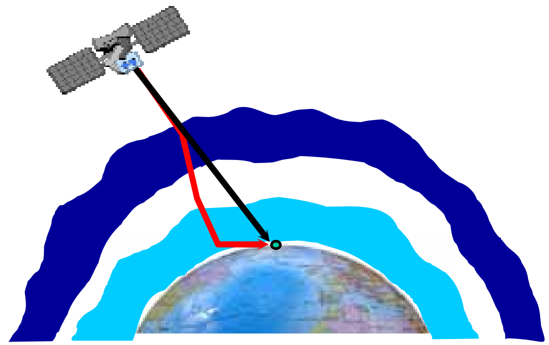
interference (jamming)

Precision is reduced by ...

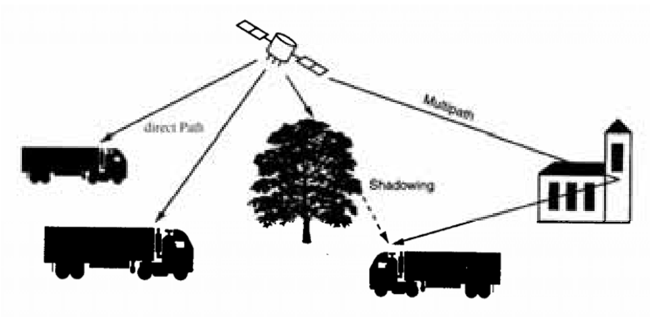
time errors (10ns = 3m)



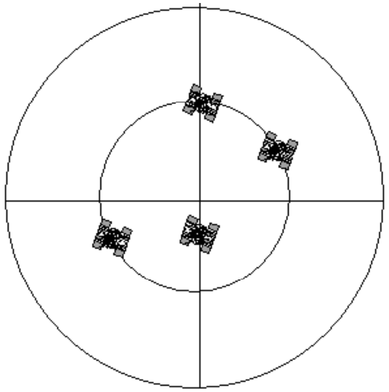
ephemerides precision



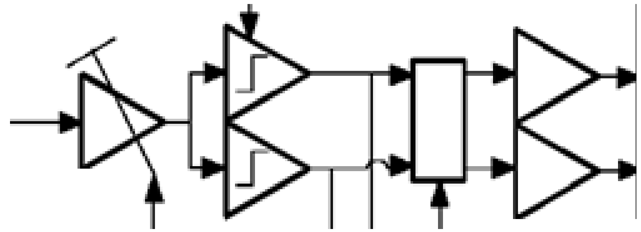
refraction in troposphere/ionosphere



multipath propagation

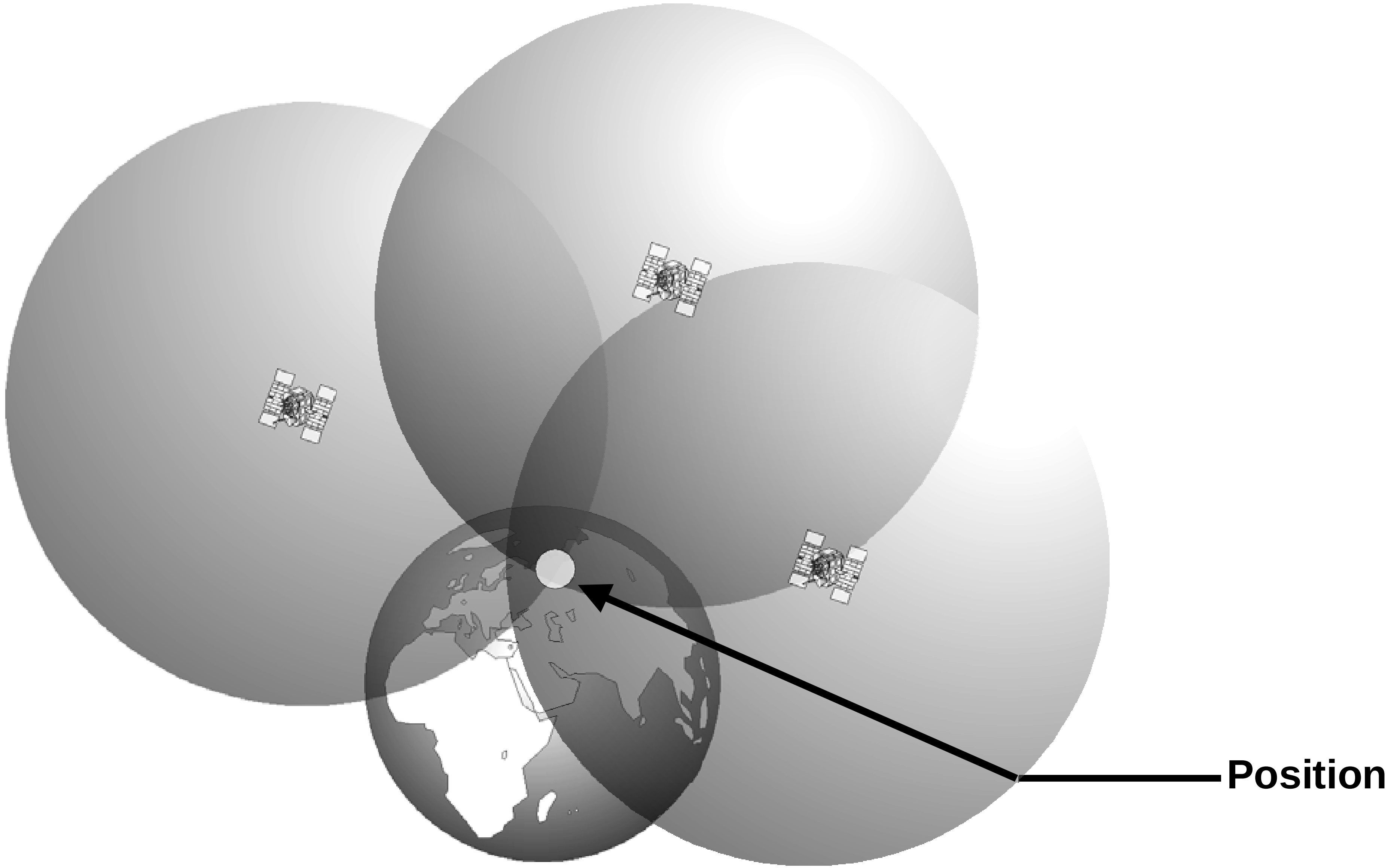


bad geometry



implementation loss

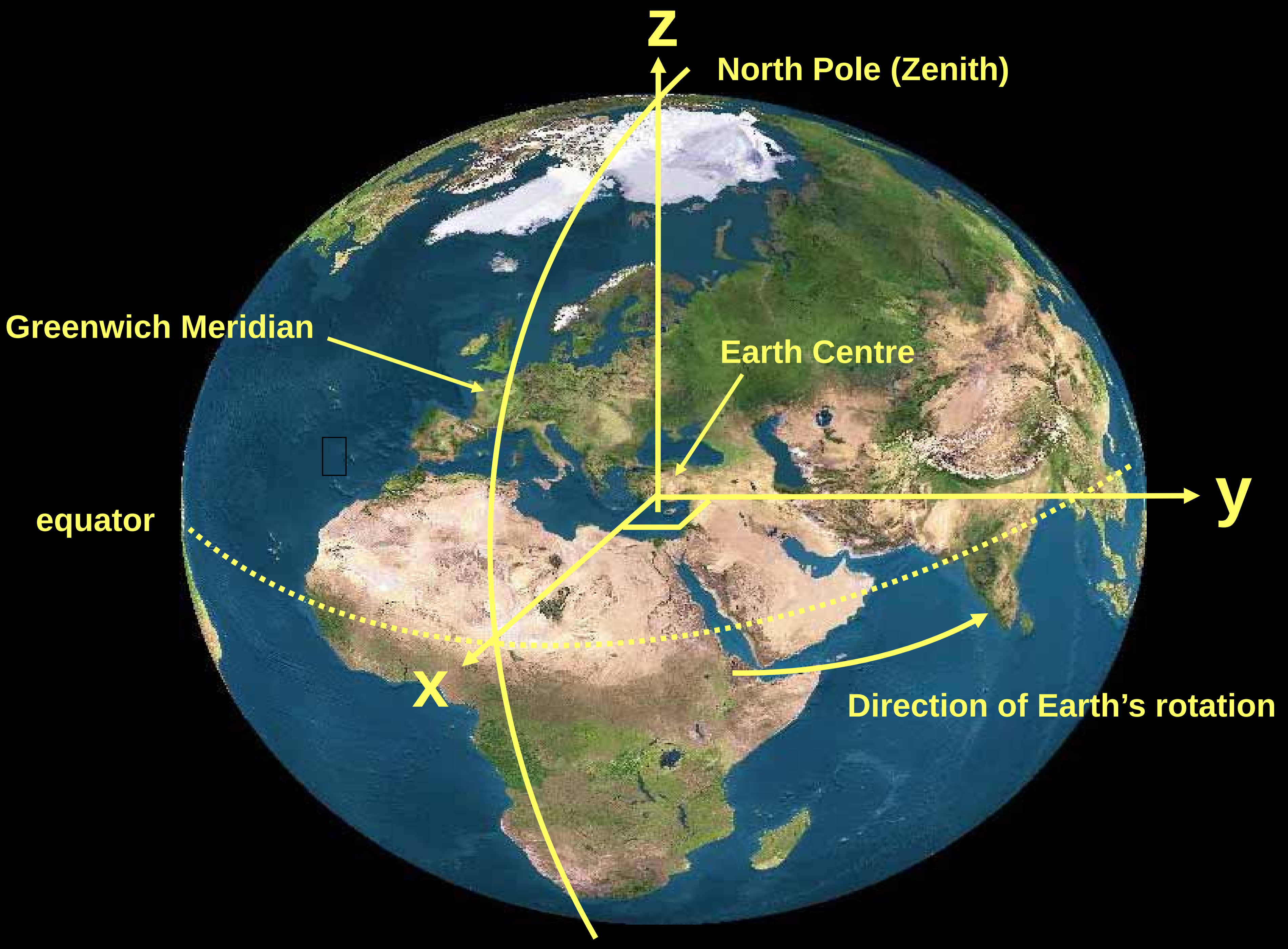
Ranging with spheres



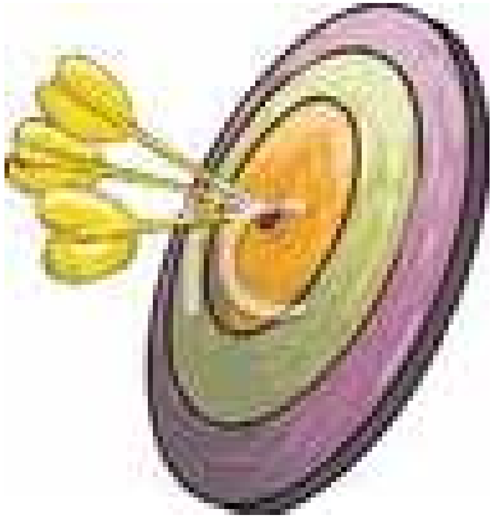
Navigation solution

$$\rho_1 = \sqrt{(x_1 - x_{\mathrm{u}})^2 + (y_1 - y_{\mathrm{u}})^2 + (z_1 - z_{\mathrm{u}})^2} + c\tau,$$
$$\rho_2 = \sqrt{(x_2 - x_{\mathrm{u}})^2 + (y_2 - y_{\mathrm{u}})^2 + (z_2 - z_{\mathrm{u}})^2} + c\tau,$$
$$\rho_3 = \sqrt{(x_3 - x_{\mathrm{u}})^2 + (y_3 - y_{\mathrm{u}})^2 + (z_3 - z_{\mathrm{u}})^2} + c\tau,$$
$$\rho_4 = \sqrt{(x_4 - x_{\mathrm{u}})^2 + (y_4 - y_{\mathrm{u}})^2 + (z_4 - z_{\mathrm{u}})^2} + c\tau,$$

Earth Centered Earth Fixed coordinate system



Quality is not performance alone



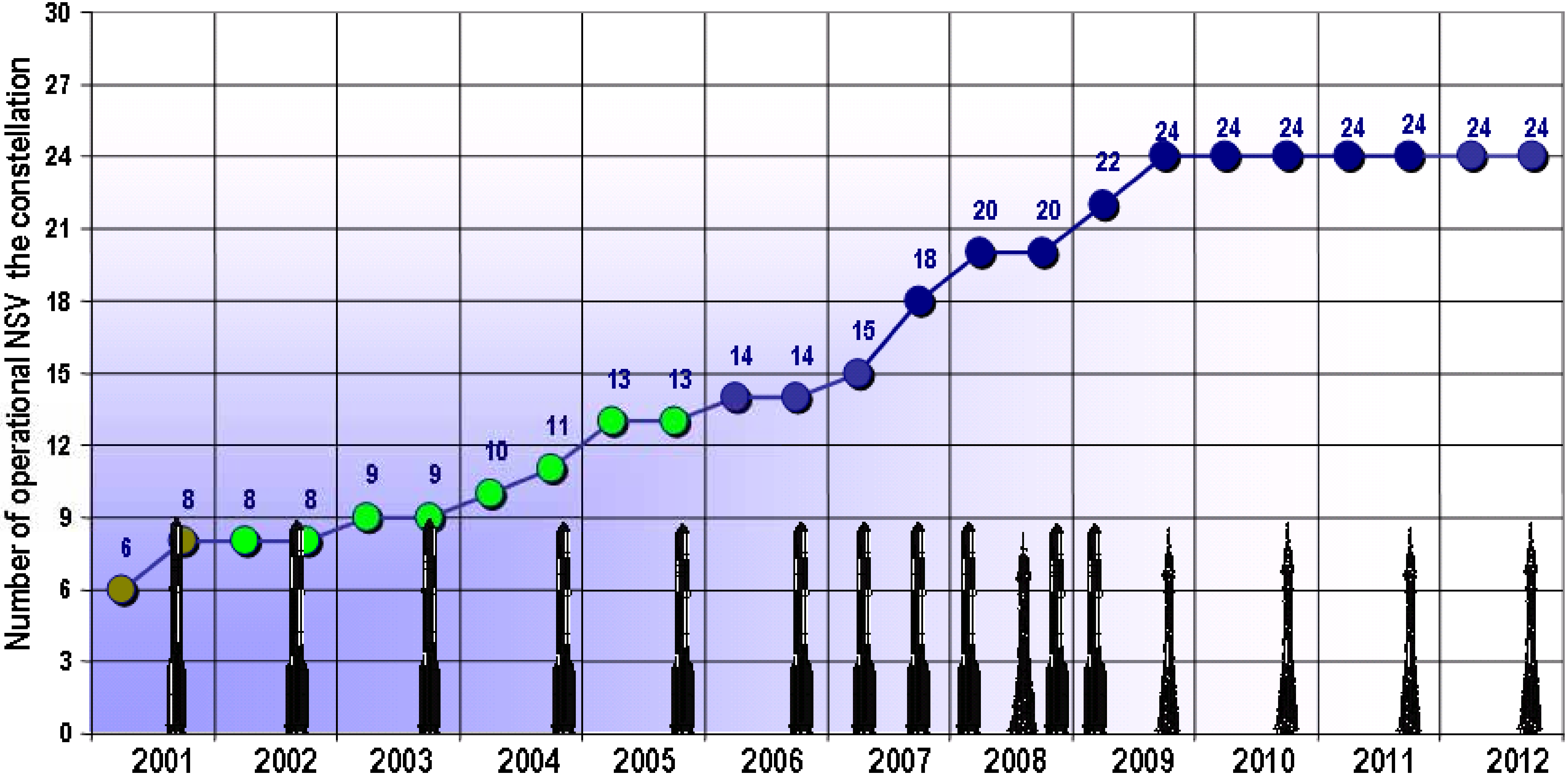
performance (precision)

availability

integrity

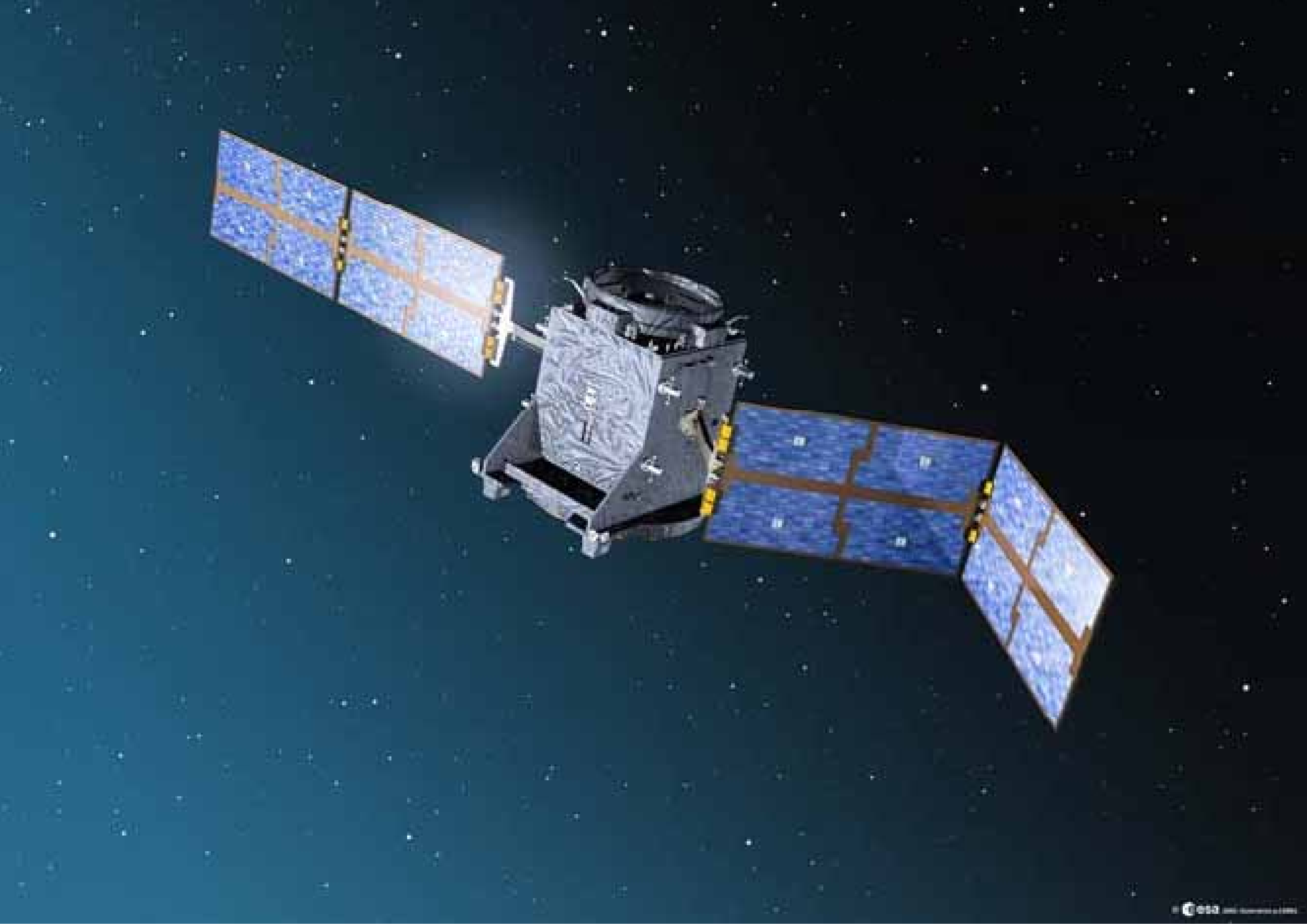
What’s in the pipeline for GNSS?

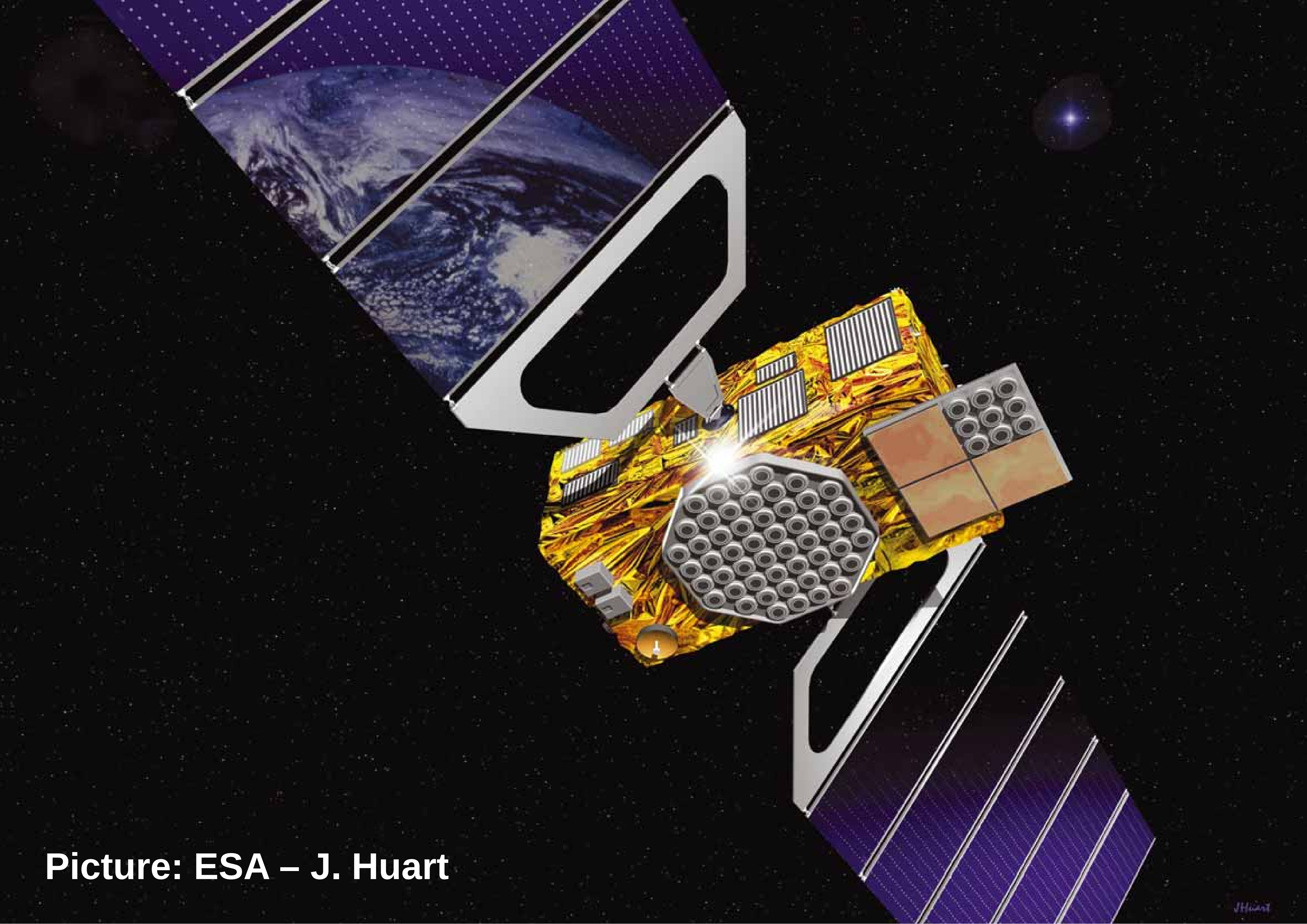
Glonass development



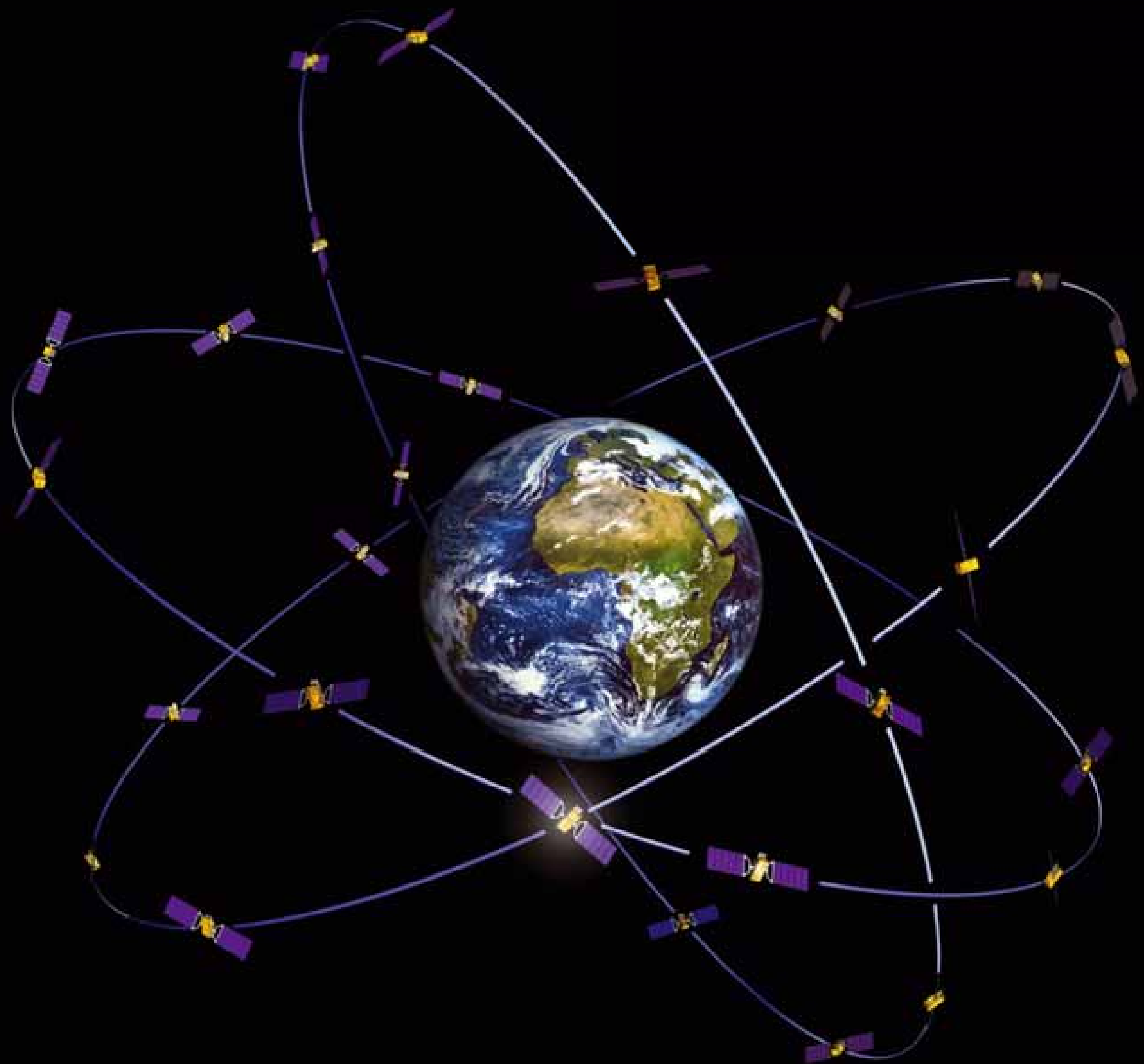

Giove-A, launched on Dec 28, 2005
Giove-B, launched on April 27, 2008


esa
www.esa.int



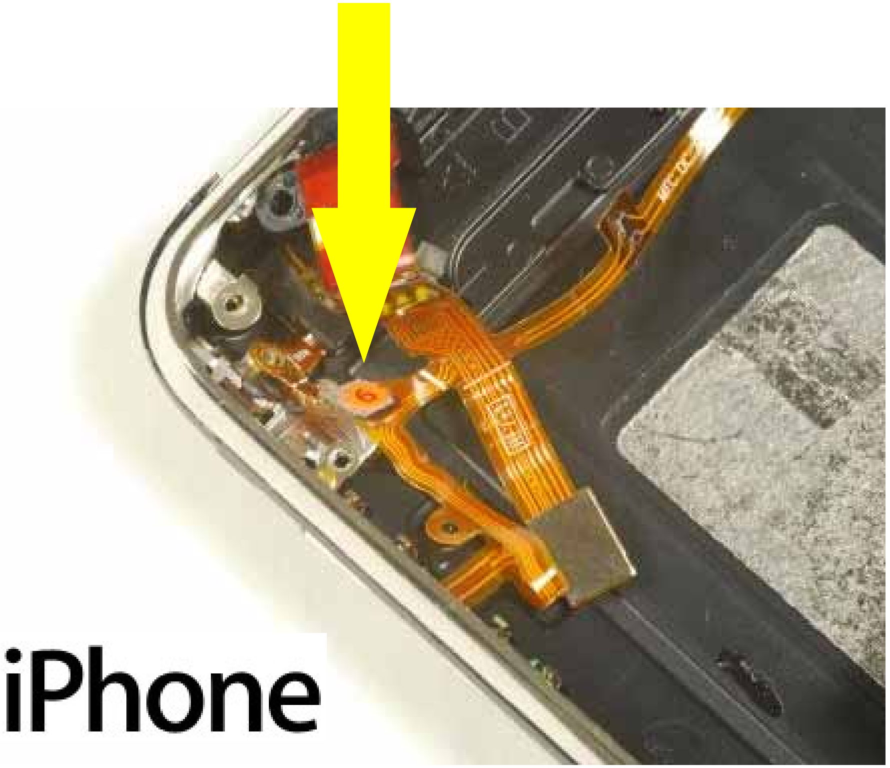


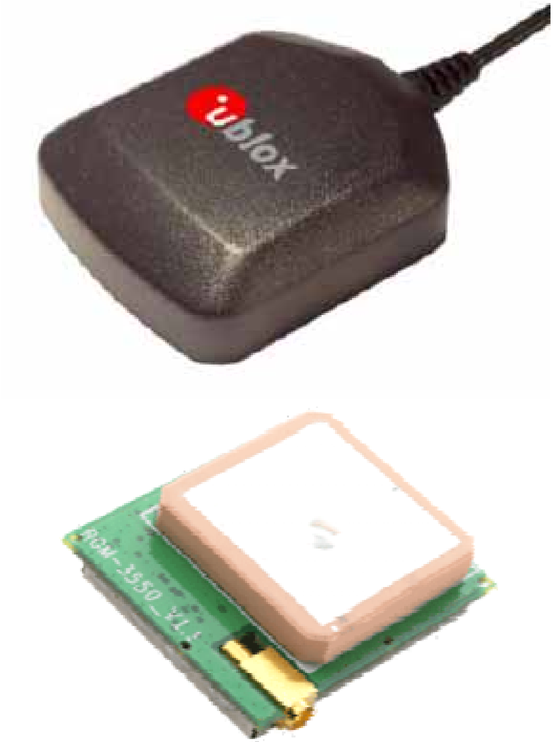
Picture: ESA – J. Huart



Picture: ESA – J. Huart

GPS antenna size





normal size

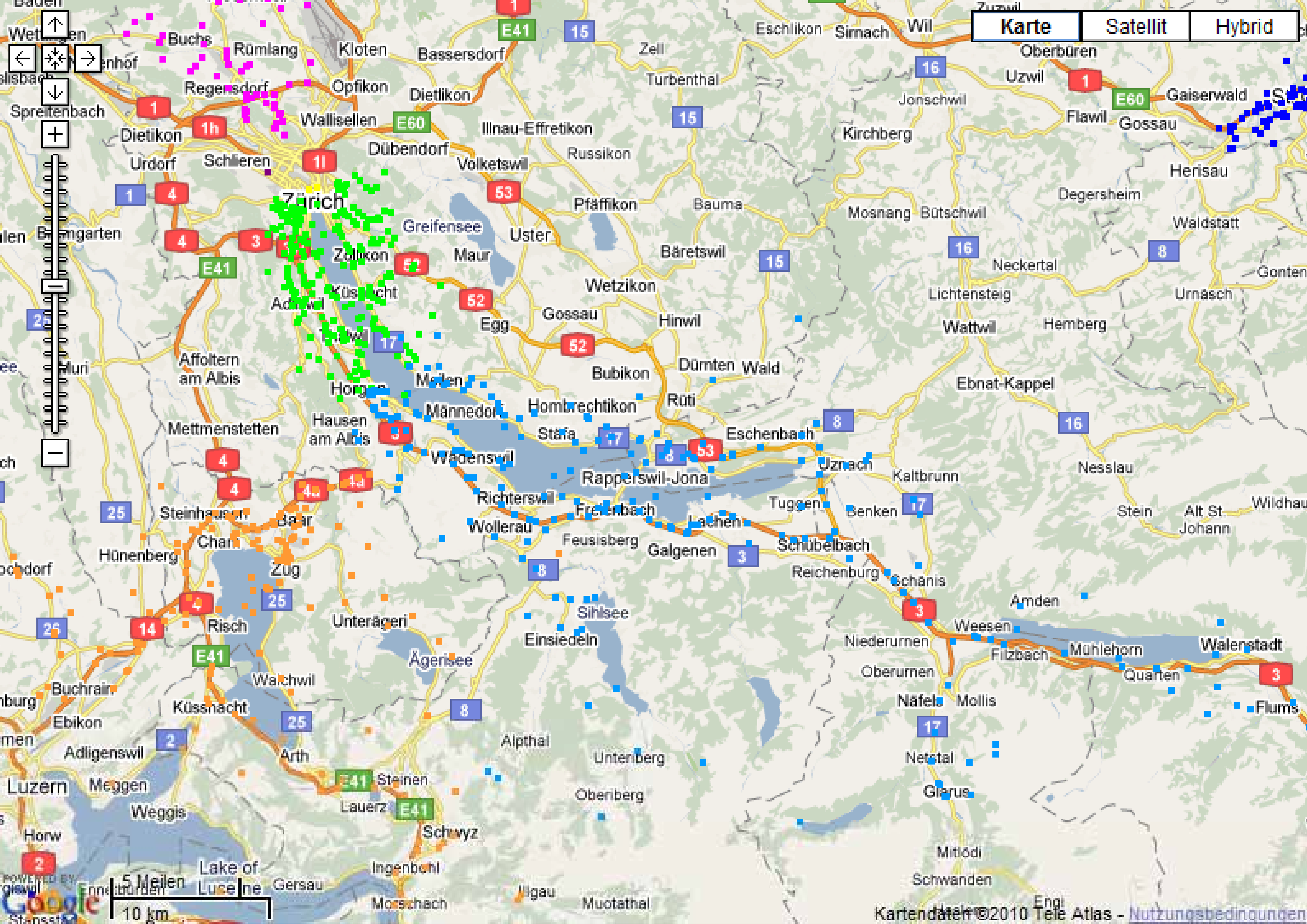
How does the iPhone get its position?

BTS database

WLAN database

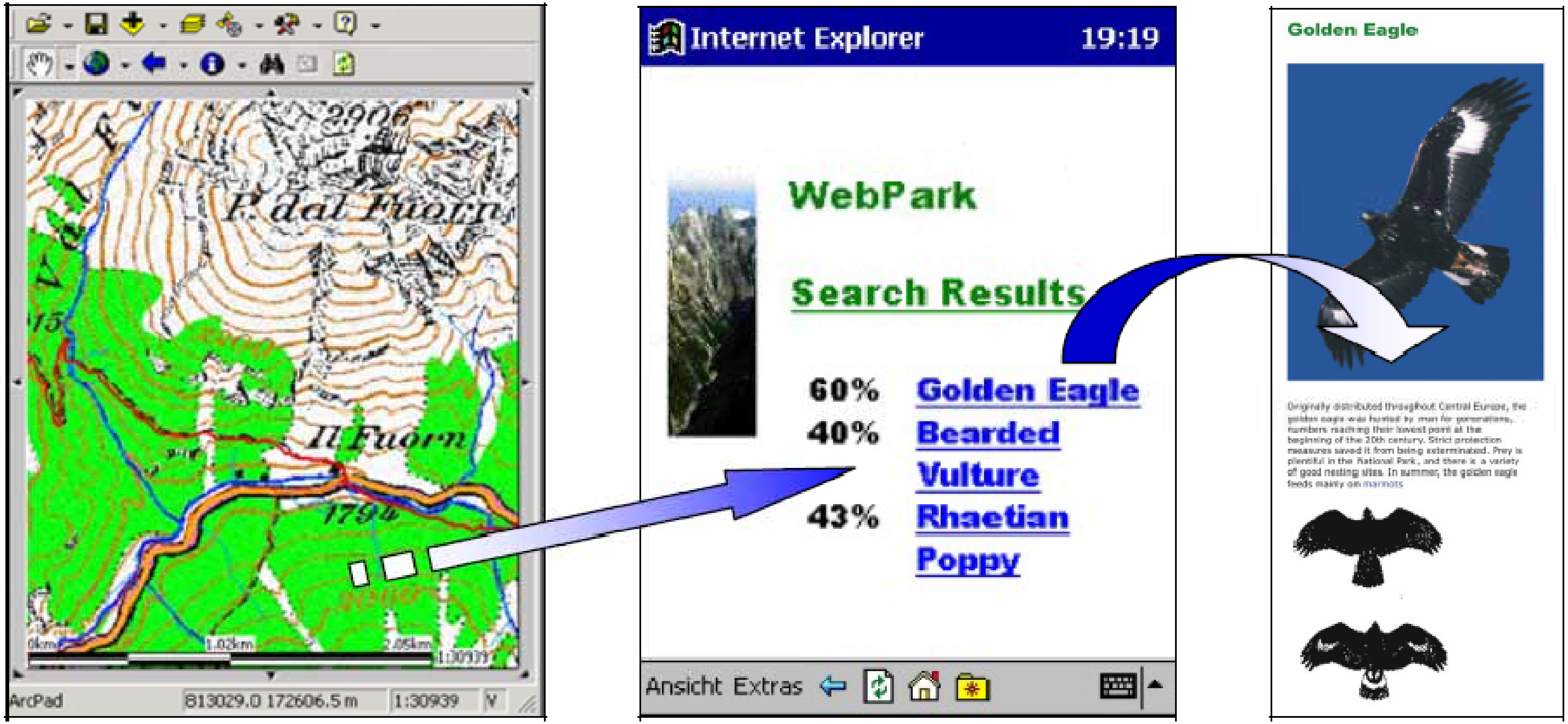
Google™

SKYHOOK® WIRELESS


Karte
Satellit
Hybrid
Buchs
Rümlang
Kloten
Bassersdorf
Regensdorf
Opfikon
Dietlikon
Spreitenbach
Dietikon
Wallisellen
Dübendorf
Illnau-Effretikon
Urdorf
Schlieren
Volketswil
Russikon
Zürich
Greifensee
Pfäffikon
Bauma
Uster
Maur
Zollikon
Bäretswil
Wetzikon
Egg
Gossau
Hinwil
Adliswil
Bubikon
Dürnten
Wald
Rüti
Meilen
Horgen
Männedorf
Hombrechtikon
Hausen am Albis
Stäfa
Eschenbach
Wädenswil
Rapperswil-Jona
Uznach
Kaltbrunn
Richterswil
Freienbach
Tuggen
Benken
Wollerau
Lachen
Feusisberg
Galgenen
Schübelbach
Reichenburg
Schänis
Sihlsee
Einsiedeln
Amden
Weesen
Niederurnen
Filzbach
Mühlehorn
Walenstadt
Oberurnen
Quarten
Näfels
Mollis
Flums
Netstal
Glarus
Mitlödi
Schwanden
Unteriberg
Oberiberg
Alpthal
Muotathal
Eschlikon
Sirnach
Wil
Zell
Turbenthal
Oberbüren
Uzwil
Jonschwil
Flawil
Gaiserwald
Gossau
Kirchberg
Herisau
Degersheim
Mosnang
Bütschwil
Waldstatt
Neckertal
Lichtensteig
Urnäsch
Wattwil
Hemberg
Ebnat-Kappel
Nesslau
Stein
Alt St. Johann
Wildhaus
Bremgarten
Affoltern am Albis
Muri
Mettmenstetten
Steinhausen
Baar
Cham
Hünenberg
Zug
Unterägeri
Ägerisee
Risch
Walchwil
Buchrain
Küssnacht
Ebikon
Adligenswil
Arth
Luzern
Meggen
Weggis
Steinen
Lauerz
Schwyz
Horw
Ingenbohl
Lake of Lucerne
Gersau
Morschach
Illgau
5 Meilen
10 km
Kartendaten ©2010 Tele Atlas - Nutzungsbedingungen


230

GPS im Nationalpark (Webpark)



Geocaching


Pfalz-
Werke
GEOCACHE Versteck - Bitte lesen
Geburtstagskerzen


OFFICIAL
GEOCACHE
PLEASE DO NOT DISTURB!
This is an official game piece.
Refer to GEOCACHING.com for details.

GPS Parachutes Into Katrina

While many Gulf Coast residents fled Hurricane Katrina's lashing winds, scientists and military pilots flew into the storm's eyewall, releasing GPS-enabled dropsondes to track and predict the strength, speed, and direction of its gale force.

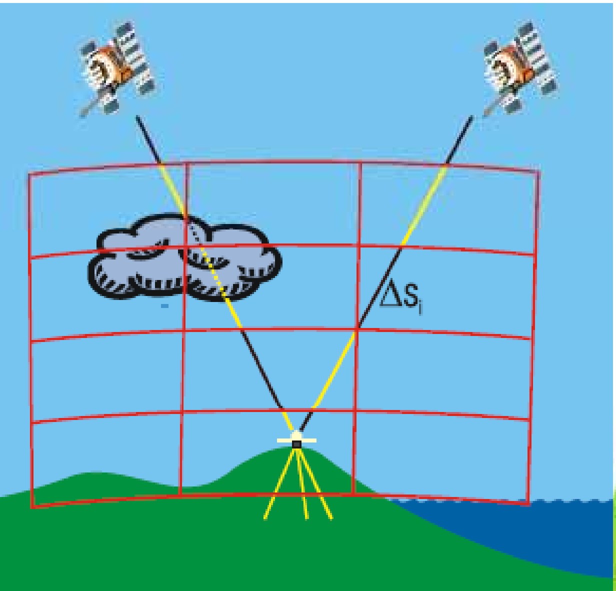
Photos Courtesy of Lt. Mike Silah, NCAR, and NOAA

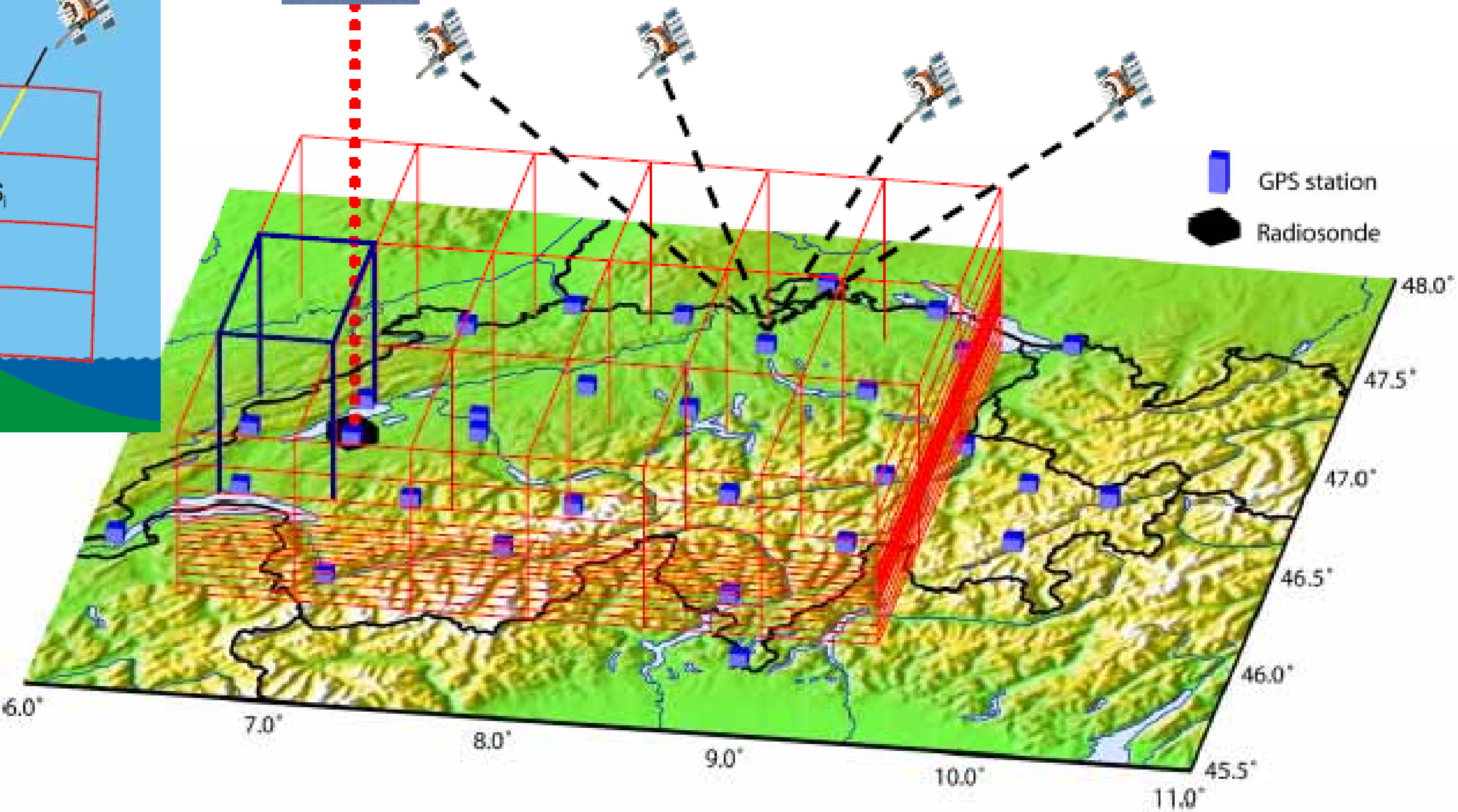
The U.S. Naval Research Lab (NRL) made 10 flights to drop 36 Airborne Vertical Atmospheric Profiling System (AVAPS) devices into the maelstrom, gathering data for the National Center for Atmospheric Research (NCAR).

The NCAR-designed dropsondes combine GPS

independent data points every 240 seconds," Hock said. "Loran reduced this to once every 30 seconds, and GPS has improved this to

Exotic applications





Applikationen am ICOM

Institute for Communication Systems

Position wird nicht (nur) vor Ort gebraucht

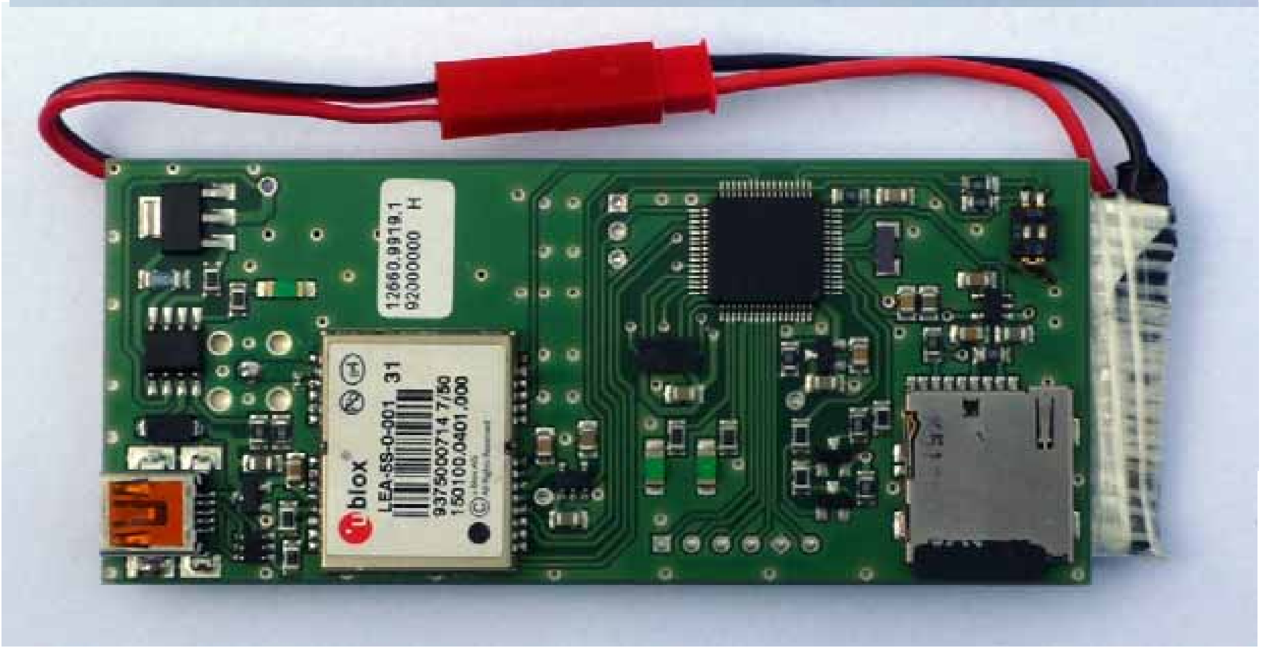
- GPS-Logger

- GPS-Tracker

- Antikollisionssystem für Busse

GPS-Logger


Kokam
LITHIUM POLYMER BATTERIES
1020mAh - 02C
3.7V T-W
www.kokam.co.kr
CIROCOMM
575


blox
LEA-5S-0-001

Kassensturz
vom 22.12.2009
um 21:06 Uhr

Weihnachtsstress: Wie pünktlich ist die A-Post?

Heute aufgegeben, morgen zugestellt: Das verspricht die A-Post. «Kassensturz» hat während der Adventszeit mehr als 100 Briefe verschickt und die Pünktlichkeit mit neuer Technik getestet: Ein Teil der Post war mit einem GPS-Empfänger bestückt. «Kassensturz» zeigt die langen Wege der Briefe.

Anforderungen an GPS-Logger

- B-Post kann mehrere Tage unterwegs sein

  → Beschleunigungssensor zur Bewegungsdetektion

- GPS-Signal kann schwach sein

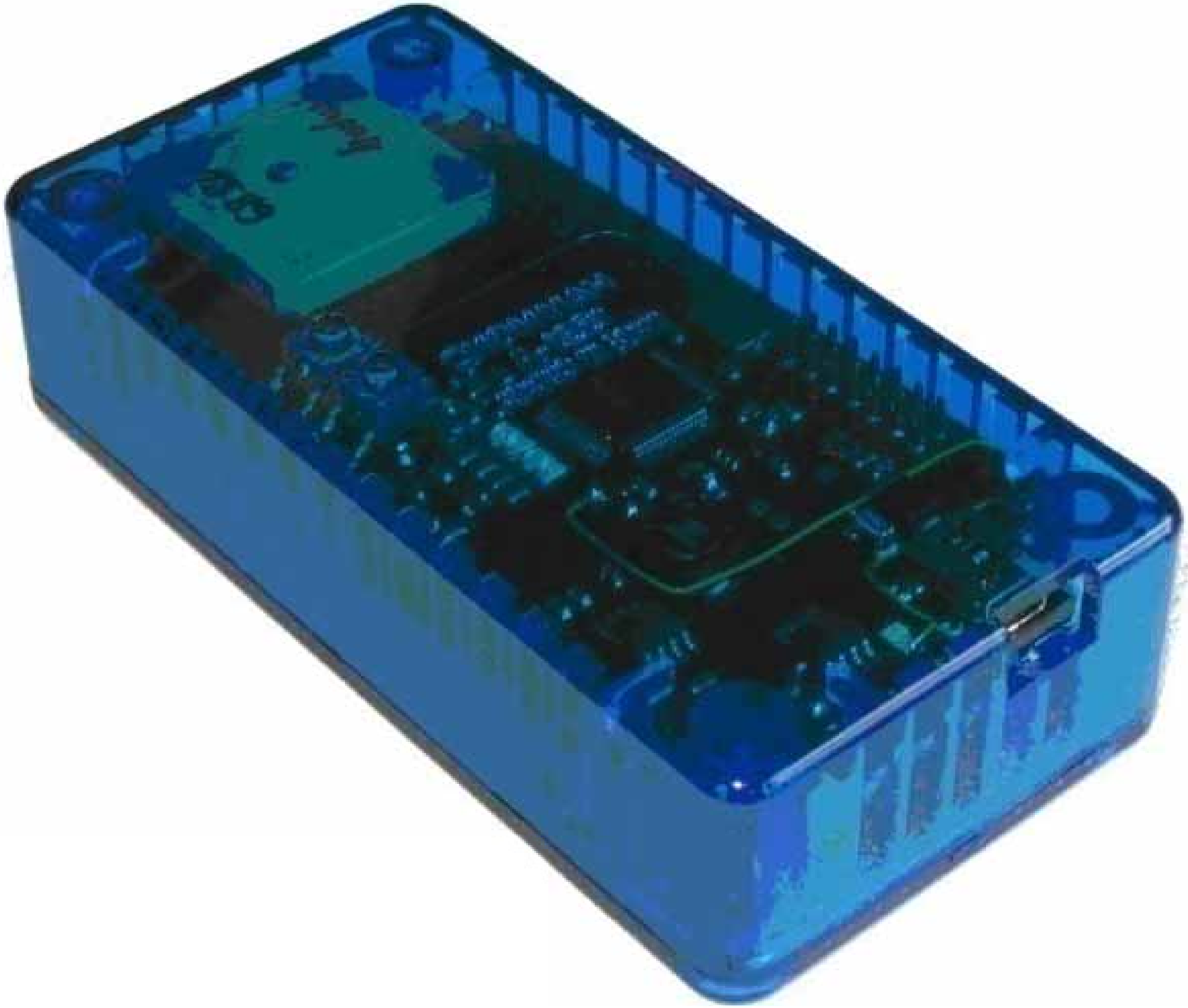
  → Einsatz empfindlicher Empfänger und Offline-Ephemeriden

- wenig Platz, tiefes Gewicht

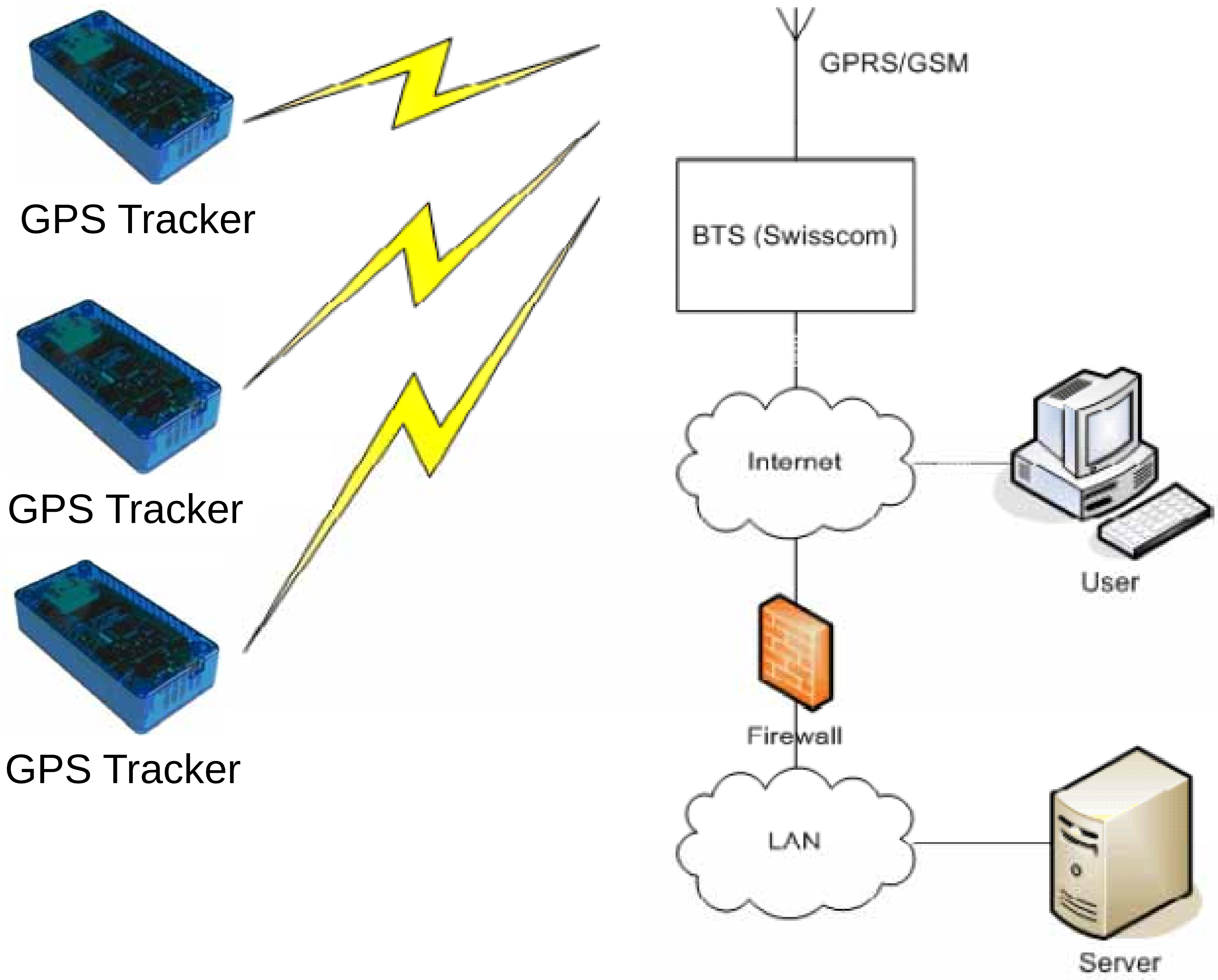
  → speziell flaches Design, flache Batterie

Grösse:	85mm x 39mm x 12mm
Gewicht:	28g (ohne Akku), 52g (inkl. Akku)
Akku-Typ:	Kokam Lithium Polymer 3.7V 1100mAh
Stromverbrauch:	100mA (Akquisition), 50mA (Tracking), 0.8mA (Standby), 5uA (OFF-Zustand, um Akku-Tiefentladung zu vermeiden)
Akku Ladestrom:	0.5A, Ladezeit ca. 2h für 1100mAh

GPS-Tracker



GPS Tracker - Systemaufbau



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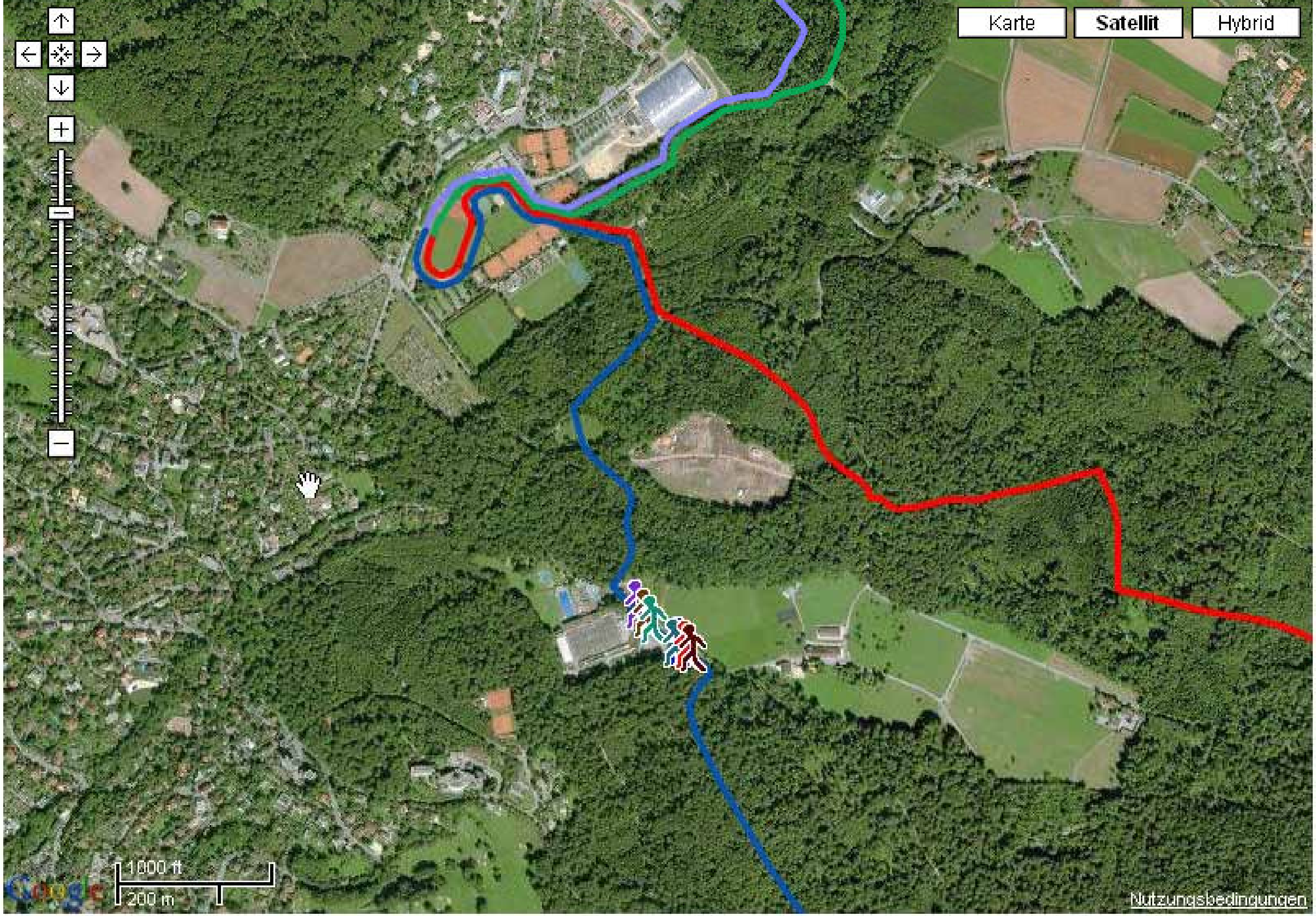


Zoom Strecke | 1

Alles zoomen

[Informationen]

Modus: Real-time Tracking

Data ID: 1177589125000

Letztes Update: 14:05:28

Icon	Name	km/h	min/km	Steigung	Höhe (m.ü.M)
	Markus Lenker	45.4	1'19	-5%	621.6
	Adrian Lenker	36.5	1'39	-6%	623.7
	Adrian Lenker	35.0	1'43	-8%	628.8

GPS Tracking - Einsatz

- SOLA Stafette
- Ironman 70.3 Rapperswil
- Ironman Zürich

- Linienbus Rapperswil (Schneider Busse)
- Ingenieurtram

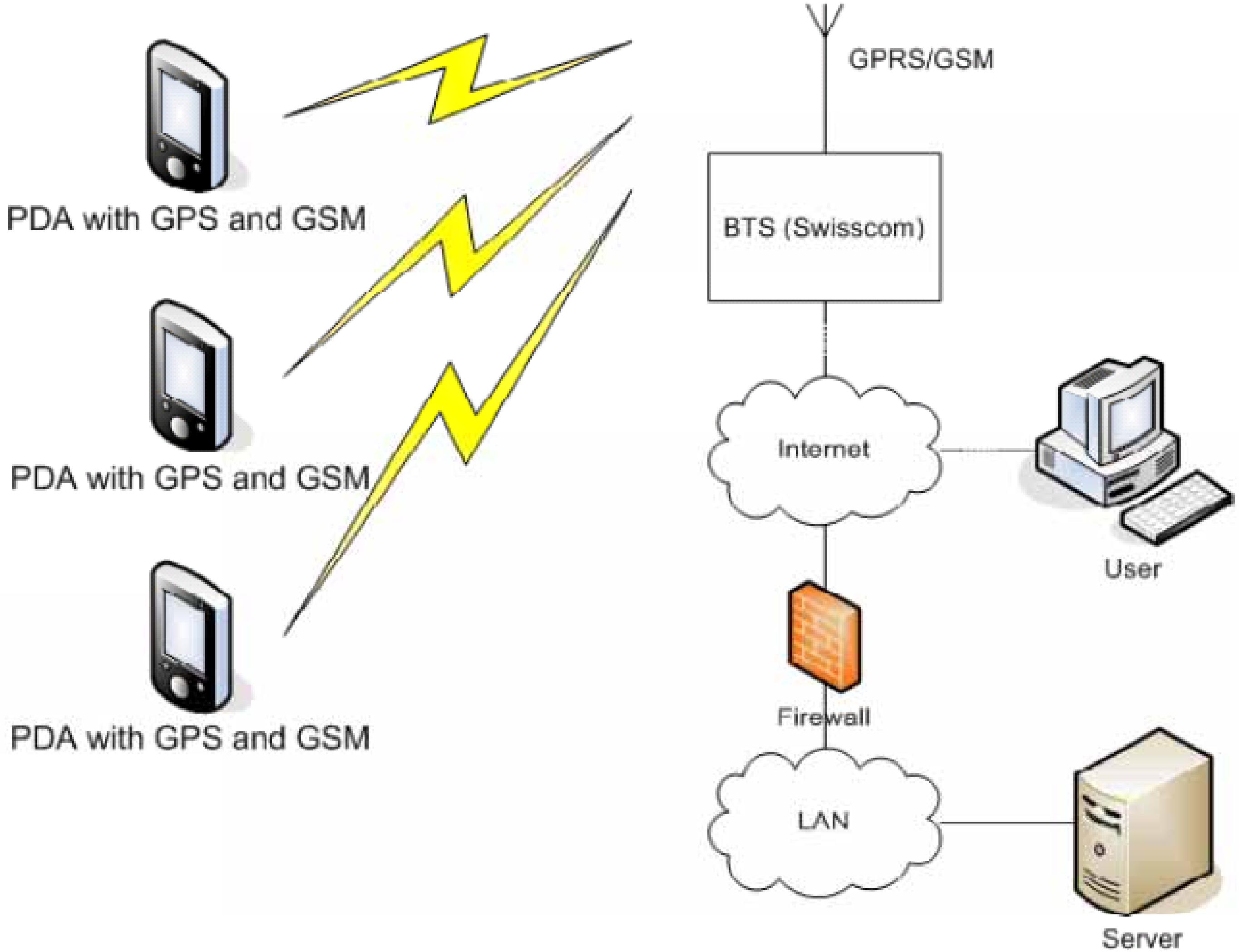
Antikollisionssystem für Busse im Gebirge


Saurer

Was ist das Problem?

- Kleine Busflotte (10-12 Busse) mit Exklusiv-Strassenzugang
- draussen: Schwierigkeit zu kreuzen (schmale Strasse, unübersichtliche Kurven, Furchen)
- drinnen: schwierige visuelle und akustische Umgebung, Vibrationen

System-Design



Fideriser Heuberge

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Fideriser Heuberge

Bus-Tracking Heuberge

powered by ICOM Institute for Communication Systems

HSR HOCHSCHULE FÜR TECHNIK RAPPERSWIL

Bus-Tracking Heuberge

Fideriser Heuberge

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HSR HOCHSCHULE FÜR TECHNIK RAPPERSWIL

150m distance

Bus-Tracking Heuberge

Fideriser Heuberge

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HSR HOCHSCHULE FÜR TECHNIK RAPPERSWIL

100m distance

Fideriser Heuberge

Bus-Tracking Heuberge

powered by ICOM Institute for Communication Systems

HSR HOCHSCHULE FÜR TECHNIK RAPPERSWIL

50m distance

Danke fürs Zuhören!

Fragen?