



Introduction to upper air measurements with radiosondes and other in situ observing systems

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- Introduction
- Review of Radiosondes past and present
- Sampling provided by radiosondes
- Errors of radiosonde measurements
- [Aircraft measurements, references provided].

Basic source on radiosondes and upper wind measurements



- Guide to Meteorological Instruments and Methods of Observation
Seventh Edition [revised 2006]
WMO- No8

Should be available in electronic form from WMO by end of 2007.

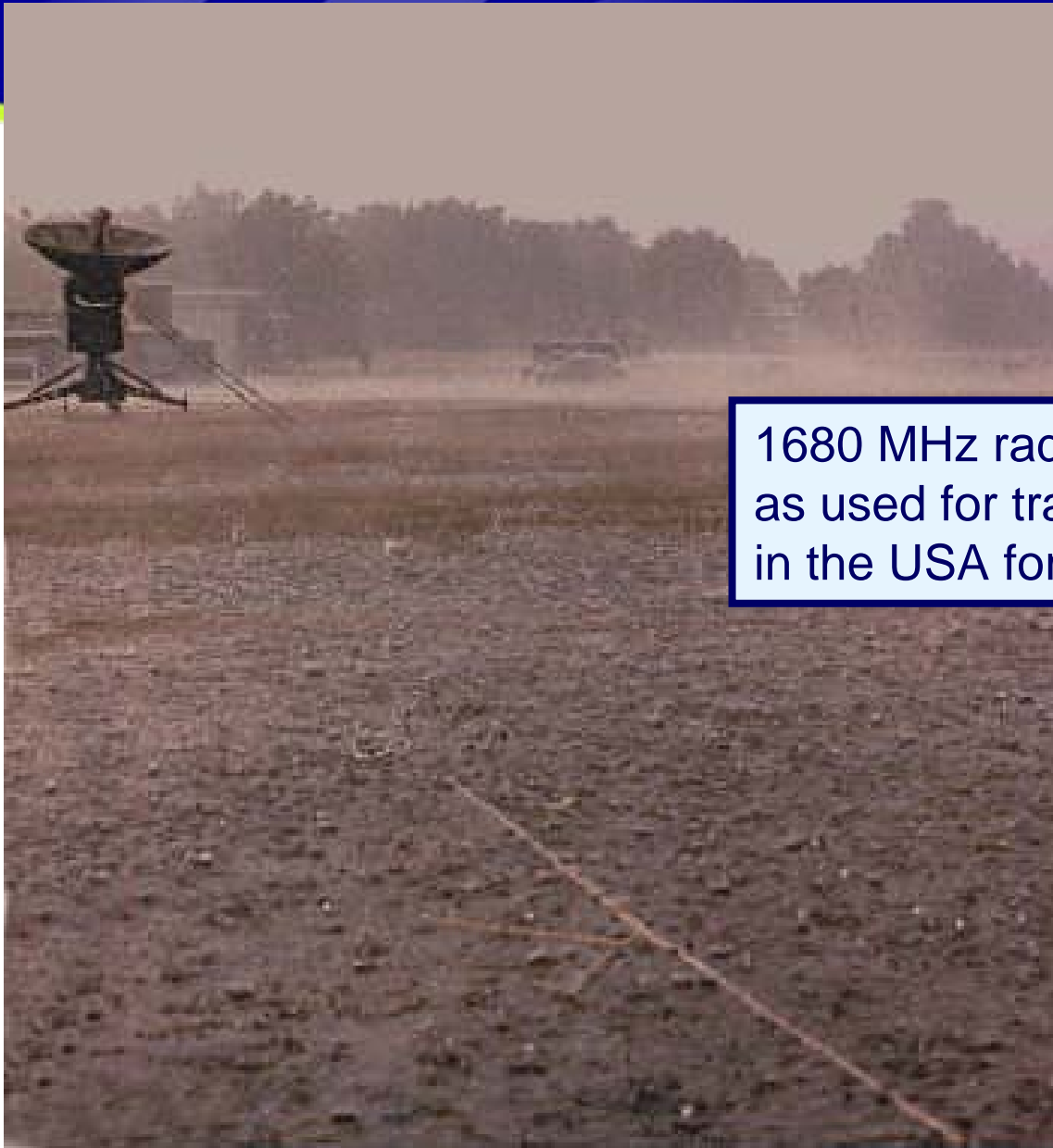
Part I

chapter 12 Measurement of upper air pressure, temperature
and humidity

chapter 13 Measurement of upper wind

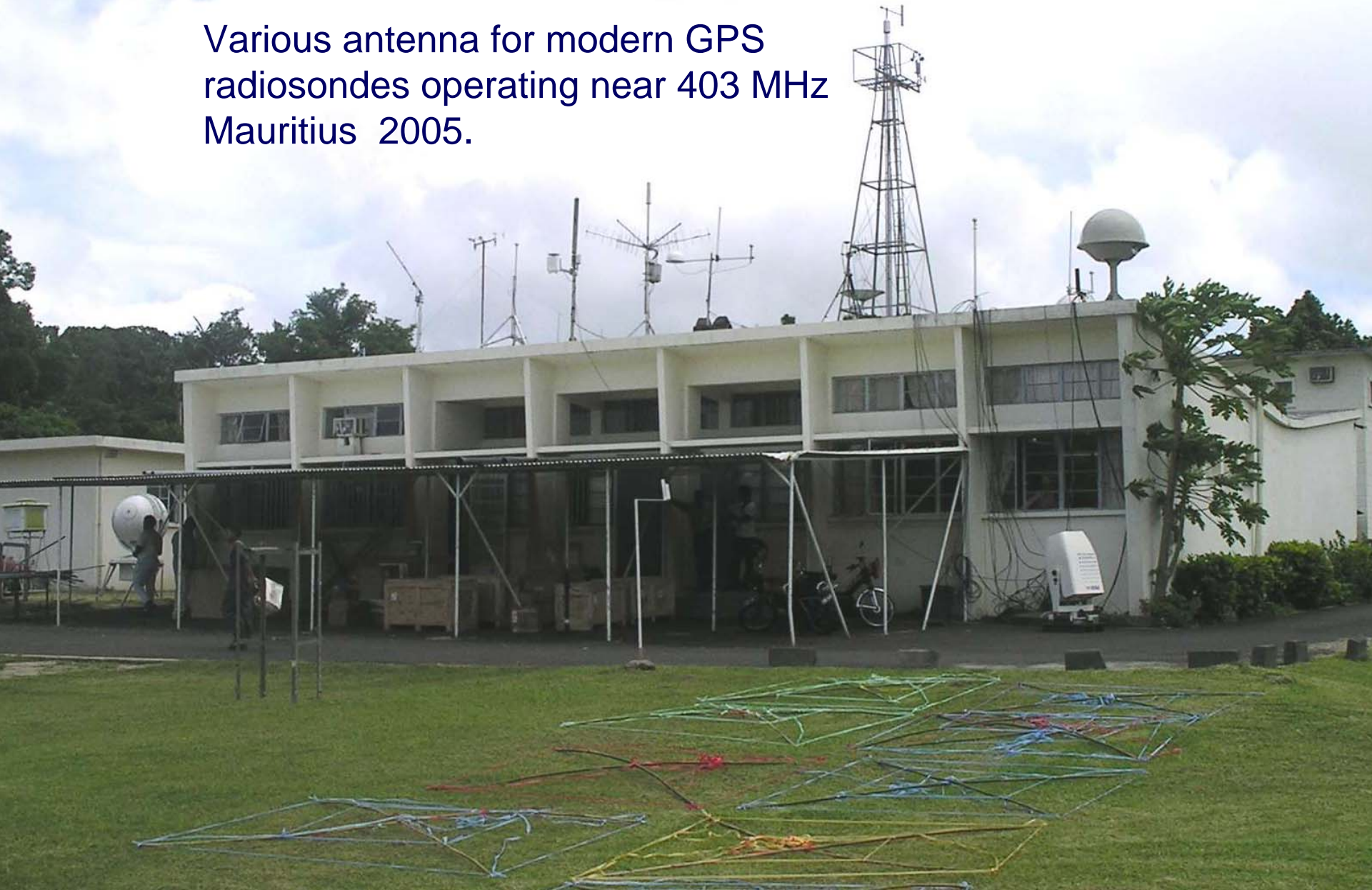
Part II

chapter 10 Balloon Techniques



1680 MHz radiotheodolite
as used for tracking radiosondes
in the USA for many years

Various antenna for modern GPS
radiosondes operating near 403 MHz
Mauritius 2005.

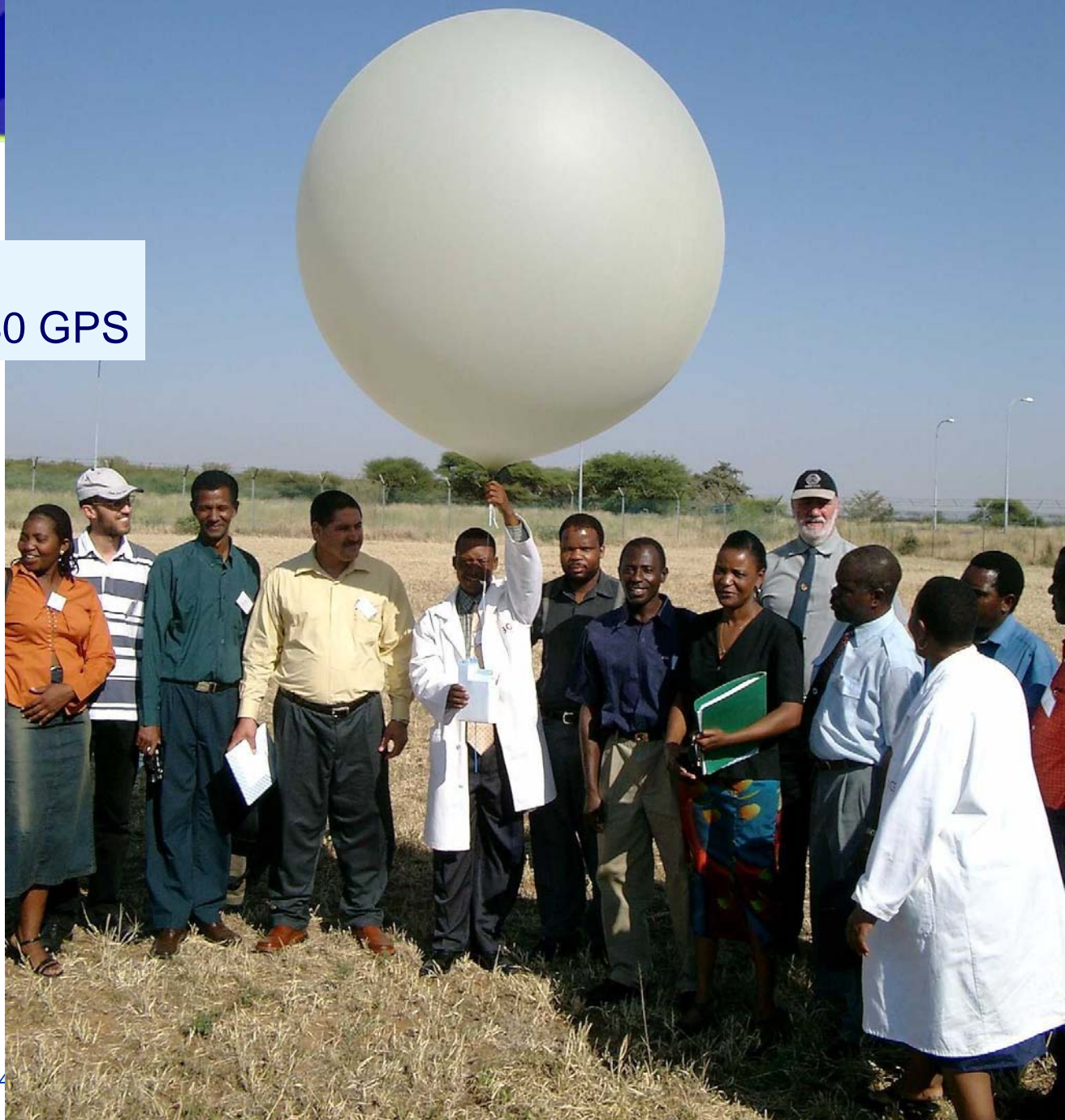


- Wind profiles from radiosondes are derived from tracking the displacement of the balloon from the launch site as a function of time.
- The radiosonde itself can be tracked using a radiotheodolite, secondary radar or reception of navigational signals by an antenna on the radiosonde. Terrestrial navigational signals Omega and Loran-C were commonly used from 1980 onwards, but now have mostly been replaced by GPS [Global Positioning System] satellite signals.
- In some countries radars were used to track a target hung under the balloon
- The rate of ascent of the balloons can be between 5 and 8 ms^{-1} , and the tracking techniques used with the older radiotheodolites allowed a resolution of about 2 minutes in wind near the ground and 4 minutes at best in the stratosphere. Now GPS signals allow a temporal resolution of a few seconds , but in fact winds are normally filtered longer than this to take out the rotation of the radiosondes in a pendulum under the balloon, since a suspension length of at least 20m is necessary to avoid contamination of the radiosonde measurements by the balloon at upper levels.

- The modern balloons routinely used by most meteorological services are either natural rubber latex or a synthetic latex. They expand as they ascend and will lift the radiosonde to heights between 20 and 26 km above the surface, before bursting. The weights of these balloons are usually between 200g and 500g
- For more expenditure on a larger balloon, weight around 1000g, heights in excess of 30 km [pressures lower than 10 hPa] can be obtained before burst. The lifting gas may be hydrogen or helium.
- Very few stations in the GCOS Upper Air network manage to observe regularly to a pressure of 5 hPa.

Most modern radiosondes are not designed to observe accurately at pressures much lower than 5 hPa. However, observing heights as high as 40 km can be obtained using special plastic [non-expanding] balloons

350g balloon
+Vaisala RS80 GPS



Review of progress with radiosondes and radiosondes in use



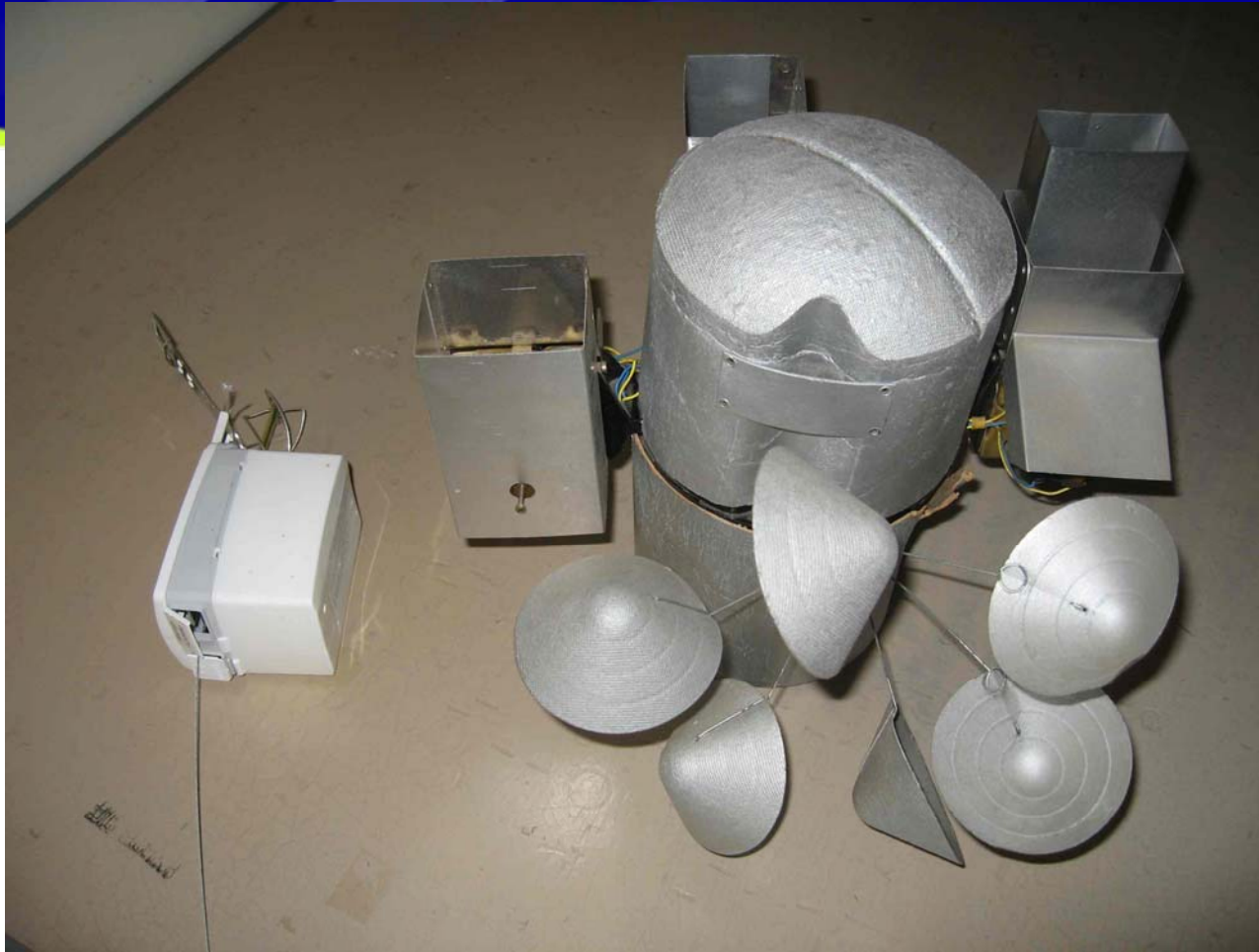
- In 1955, the radiosonde was the primary source of upper air information for meteorologists.
- Large numbers of people were employed at an upper air station. Four to six persons on a shift. All reports were produced by hand from traces on chart recorders or decoded from coded radiosonde signals by hand.
- Radio reception was relatively poor compared to modern systems, and this limited the ability to compare the output from different radiosondes flown together.
- Hence, the WMO Radiosonde Comparison held in Payerne in 1956 was unable to provide any serious insight into the relative performance of the radiosonde types, and the reference radiosondes tested in WMO Reference Radiosonde Comparison conducted in 1968 did not agree very well.
- In this period, the quality of the message was strongly dependent on the motivation of the staff to perform the calculations correctly.

Assembling the radiosonde rig
in 1955

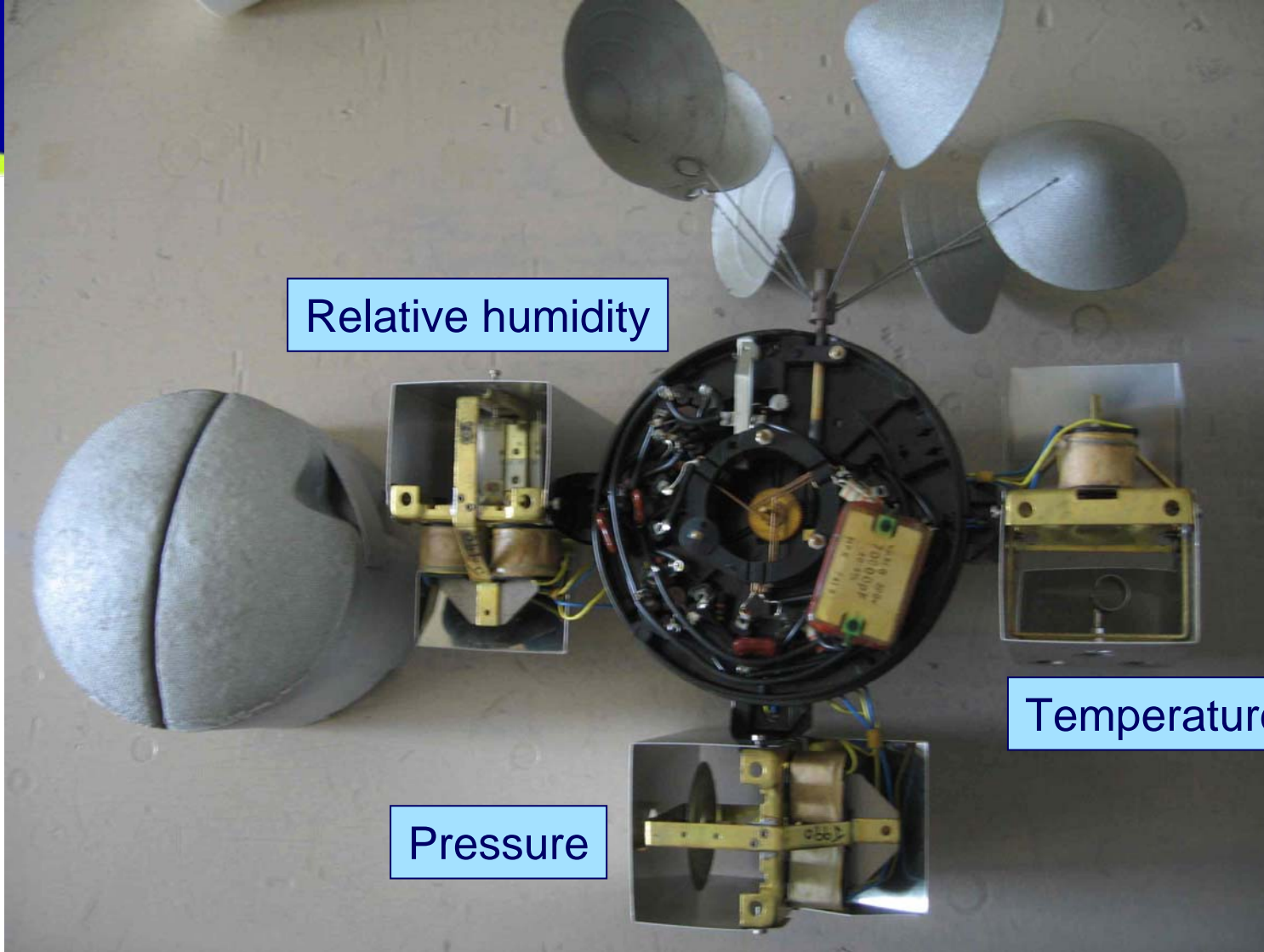


All ready to launch the radiosonde





UK radiosonde used for several decades prior to 1978, Note windmill turned a mechanical switch which selected which sensor assembly controlled the transmission to the ground. Thus, sensor repeat sampling was slow and not at a constant rate.



The sensors were mechanically linked to a variable inductance
Which controlled the frequency of transmissions
to the ground at 28 MHz.

Indian Radiosonde groundstation in 1999



- Early radiosonde signals were transferred to special working diagrams after decoding or were made available on chart recorder outputs. The messages sent were derived by hand.
- So the results were reported in a code that allowed the values of temperature and dewpoint depression and wind to be reported at a set of standard pressure levels, e.g. 850, 700, 500, 300, 200, 100, etc. hPa. Here the values were supposed to be those actually measured. In addition the message contained an additional set of levels that allowed the temperature profile structure to be reproduced to ± 1 C in the troposphere and ± 2 C in the stratosphere, and the relative humidity profile to ± 15 per cent.
- When radiosonde observations started these coding errors were probably not much different to the errors in the sensor measurements, but this is not the case today. The sensor sampling rates in the old radiosondes were not high, but now detailed profile observations with the sensors sampled every second, can be exploited by taking detailed data from the ground system archives and not relying on the approximations in the TEMP code. A new BUFR code representing the detailed data is currently in the process of implementation.

- Information from satellite remote sensing was expected to replace radiosondes by 1990.
- However, advances in electronics were allowing the introduction of improved data transmission and reception, electronic multiplexing of sensor output, improved sensors and affordable computers to process data semi-automatically or automatically.
- Thus, those countries able to take advantage of these innovations were able to change the quality and accuracy of radiosonde output, and to make it very much less dependent on the operator motivation.

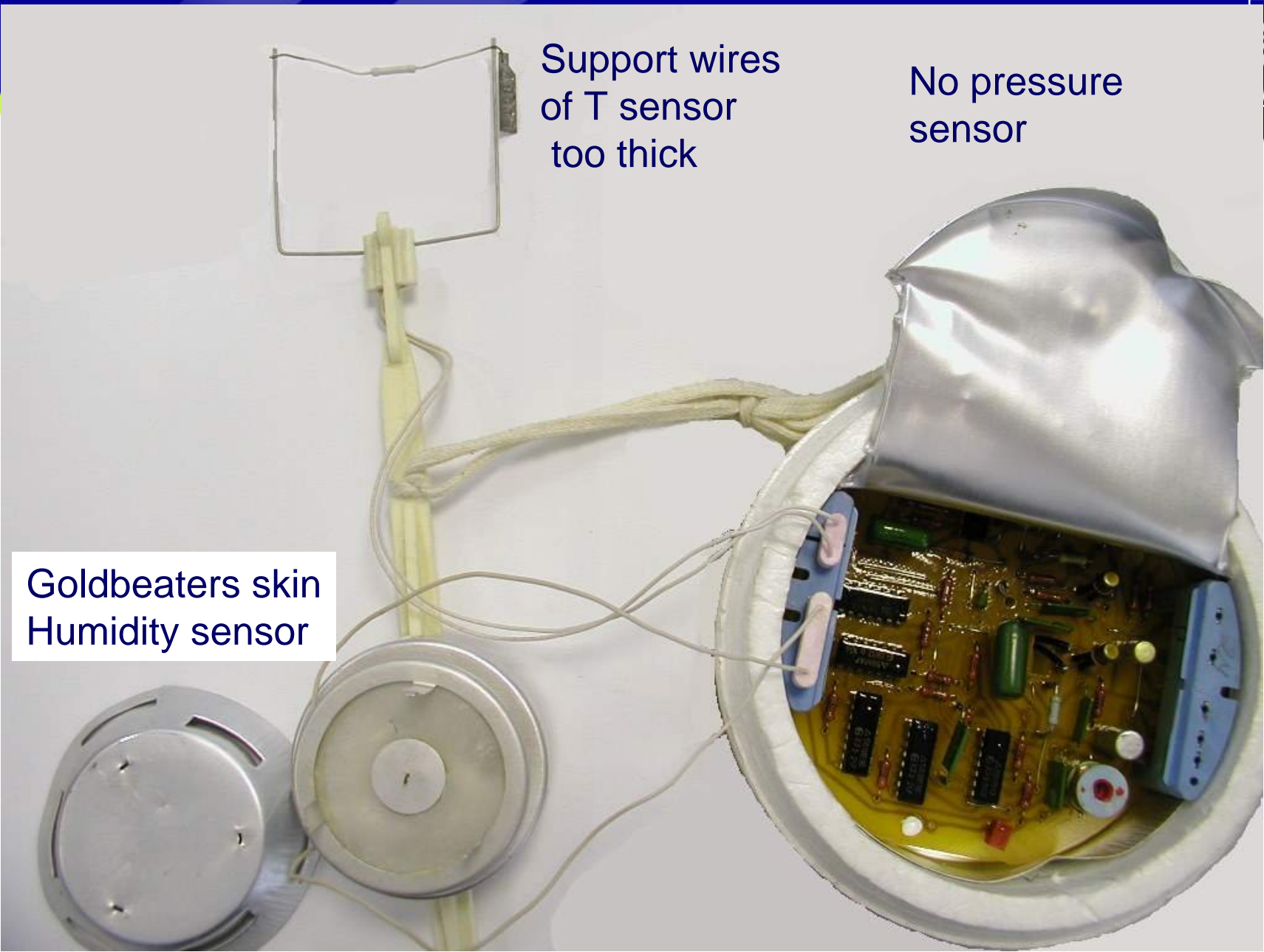


One type of Russian radiosonde still in use

Support wires
of T sensor
too thick

No pressure
sensor

Goldbeaters skin
Humidity sensor



Meteorit II, secondary radar, now obsolete



Modern type of 1680
MHz radiotheodolite

Chinese secondary radar

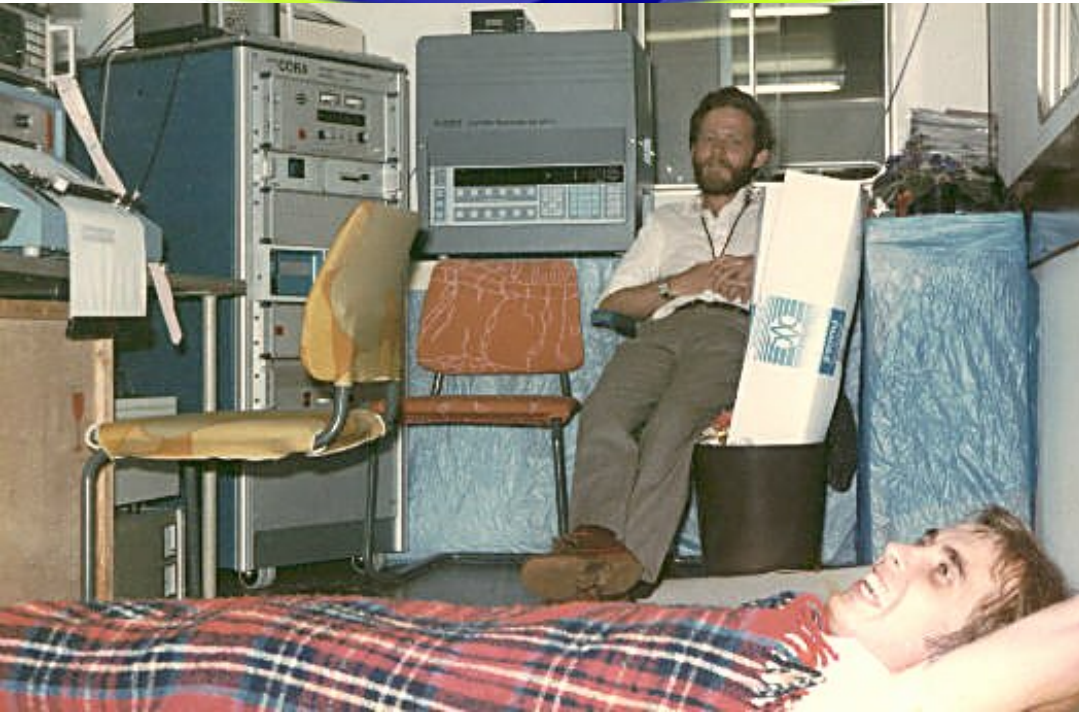


Chinese radiosonde, phased out 2005 -2007
replaced by modern system with accuracy much higher



Coding drum

Temperature sensor,
bimetallic spiral



First system where operators could rest during an ascent



The size of radiosondes in 1984 during the first modern WMO test is much larger than those used now and the measurements less accurate

- A new generation of radiosondes has been introduced exploiting ASIC [Application Specific Integrated Circuits] developments. This allows the use of decoded GPS signals, giving very accurate wind measurements and accurate height measurements. Occupied bandwidth has been reduced on standard radiosondes, and transmissions are more stable than in earlier standard designs.
- Temperature and relative humidity sensors have also been improved to extend the useful vertical range of both measurements, so reliable temperatures can be measured to pressures as low as 5 hPa and reliable relative humidity to temperatures as low as -70 deg C.
- Aircraft measurements are expected to reduce the number of regular radiosonde launches
- Ground-based remote sensing systems are being developed to provide continuous upper-air measurements at high temporal resolution, but often lower vertical resolution.



Two examples of modern
GPS radiosondes
Internal electronics, 2006



- The design and characteristics of radiosondes in use has changed radically with time, so that representations of radiosonde systems stuck in the past is largely untrue.
- However in some countries , relatively poor systems still remain, so that not all of the 700 civilian stations making measurements daily have the same error characteristics
- The better radiosonde are able to meet the most exacting user requirements for all operational use and scientific studies, apart from possibly the very high accuracy requested for relative humidity in the upper troposphere for climate trend studies.
- Detailed description of the various radiosonde observing principles can be found in the CIMO Guide[2006].
- A knowledge of radiosonde errors is essential when using radiosondes to compare with remote sensing measurements. This includes an understanding of the representativeness errors from the rapid ascent of the balloon through the vertical structure of the atmosphere, usually 1 km in the vertical in about 3 minutes.