Legacy S/X
- Many accomplishments
- Long history
- Scale & Orientation

VGOS Broadband
- 1-mm positions
- 24/7 operations
- Rapid turn-around

VGOS Operational Readiness

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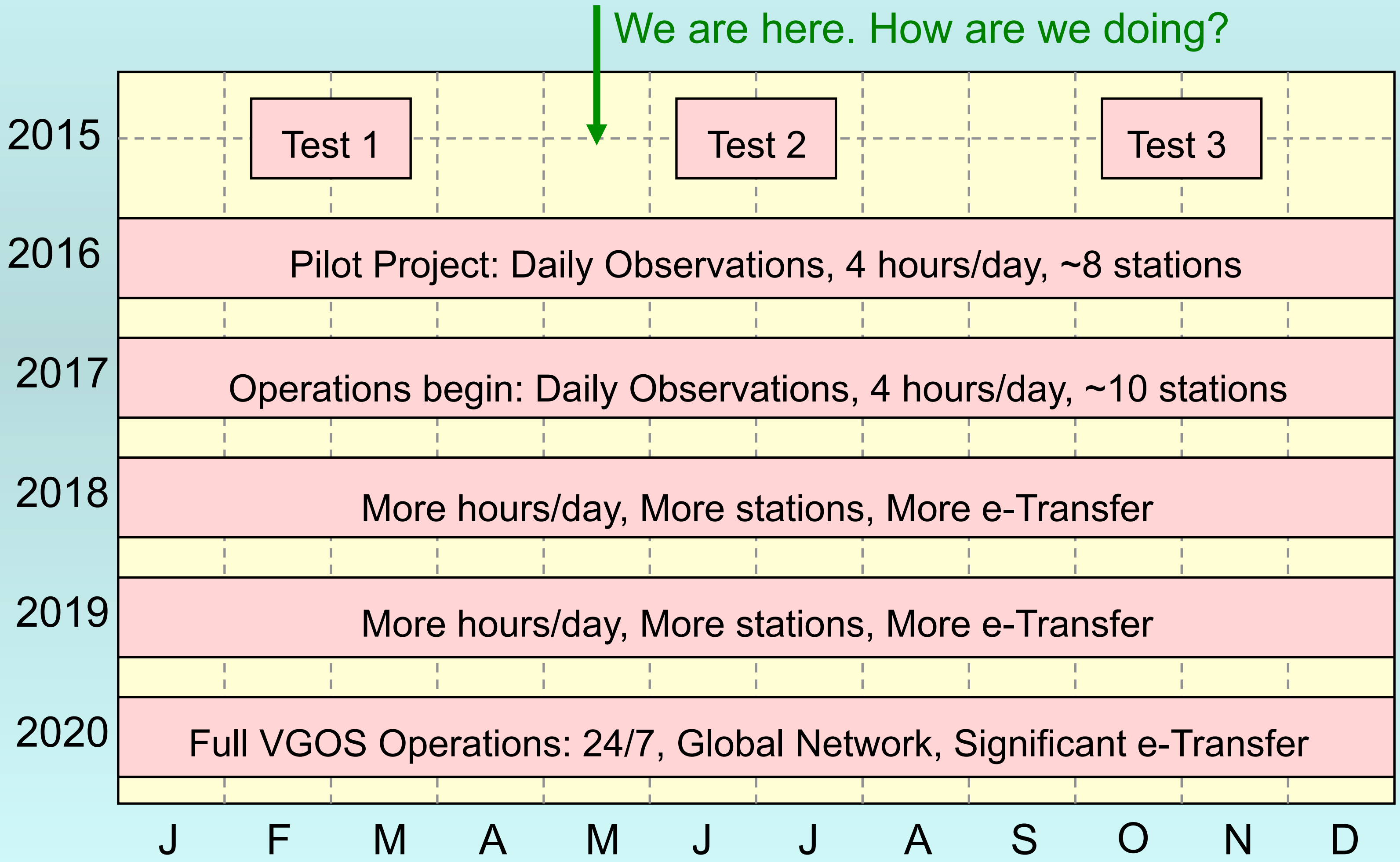
VGOS Observing Plan

Adopted March 2014 at IVSGM in Shanghai



How are we doing?

- VGOS test campaigns require:
  - Existence of efficient operational processes
  - A small network using broadband signal chains

- … But neither were in place by the start of 2015, so
  - VGOS test campaigns have been delayed

- However, lots of important work is being done …

Operational Process Development

- Operational process development is underway using Westford/GGAO baseline as a test bed
  - ***VEX2*** definition has been completed
  - ***Automation of control of station equipment*** is progressing based on the Field System
  - ***Automation of processes*** is underway (but more to do), e.g.
    - Sked, Drudge, Correlation, Fringing, Analysis
  - ***Parallel universe*** is being established
    - Equivalent of master schedules, etc but for VGOS only
- Tests are carried out every two weeks
  - Currently 1 hour duration
  - Processes are becoming more efficient with each session
  - Longer sessions to begin soon
  - A longer baseline would be useful to evaluate impact of source structure.

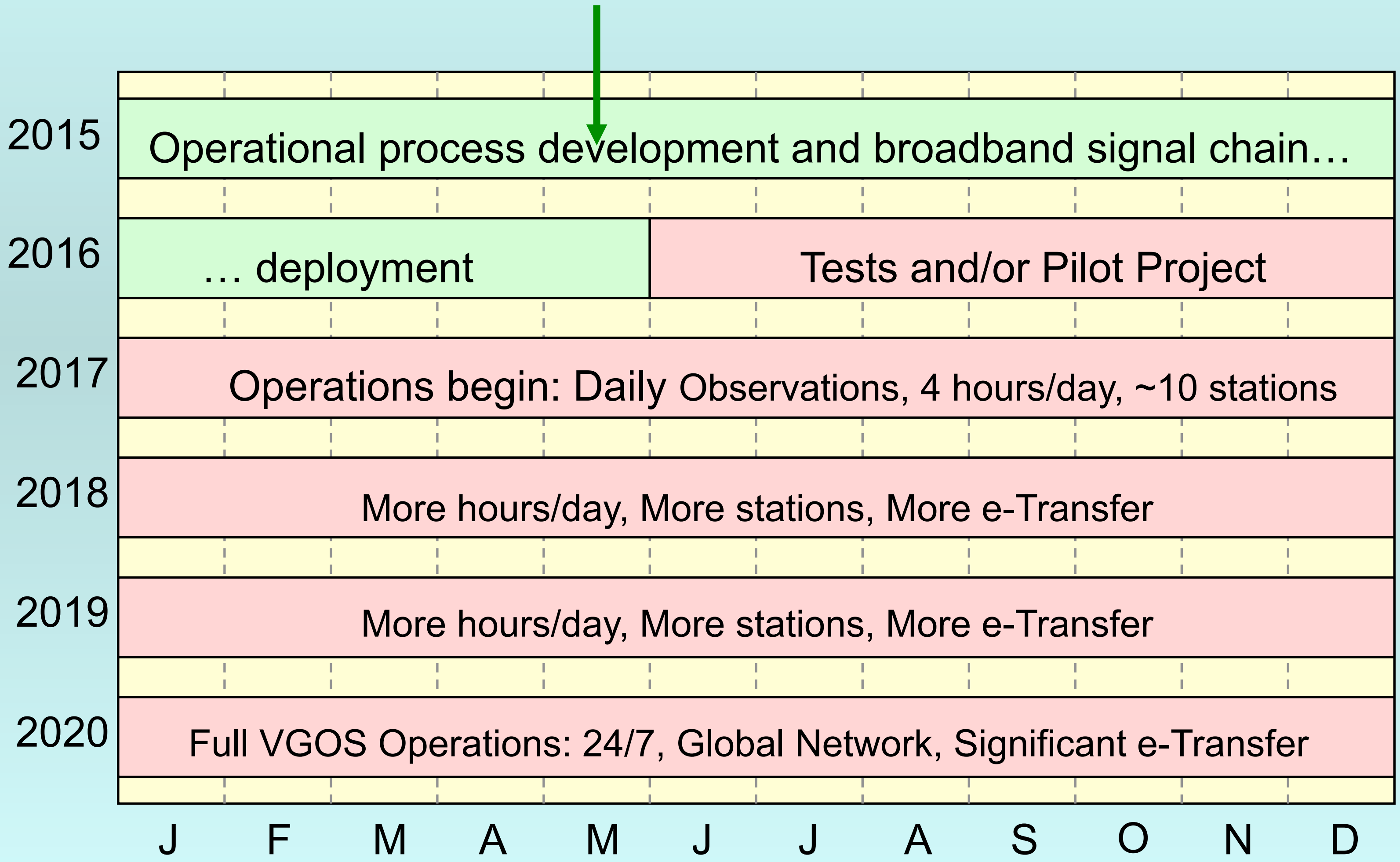
Establishment of broadband signal chains

- VGOS Antenna construction is progressing well
  - a number of antennas are complete with others under construction or funded.
- Broadband signal chains are being established at a number of antennas, including:
  - Front end, i.e. feed, LNA, calibration, cryogenics
  - Data down link, usually fibre
  - Flexible down converters
  - Digital back ends (DBEs)
  - Data systems (disk recorders and Internet interfaces)
  - Remote control, ancillary systems, and monitor/control (MCI)
- Development schedules are much better understood now.
- Seven stations expect to have broadband signal chains operational by mid – 2016.
  - Westford, GGAO, Kokee, Wettzell, Yebes, Noto, Hobart, perhaps others

Revised VGOS Observing Plan

First consistent daily products delayed ~1 year

Too early to say if full operations in 2020 are affected



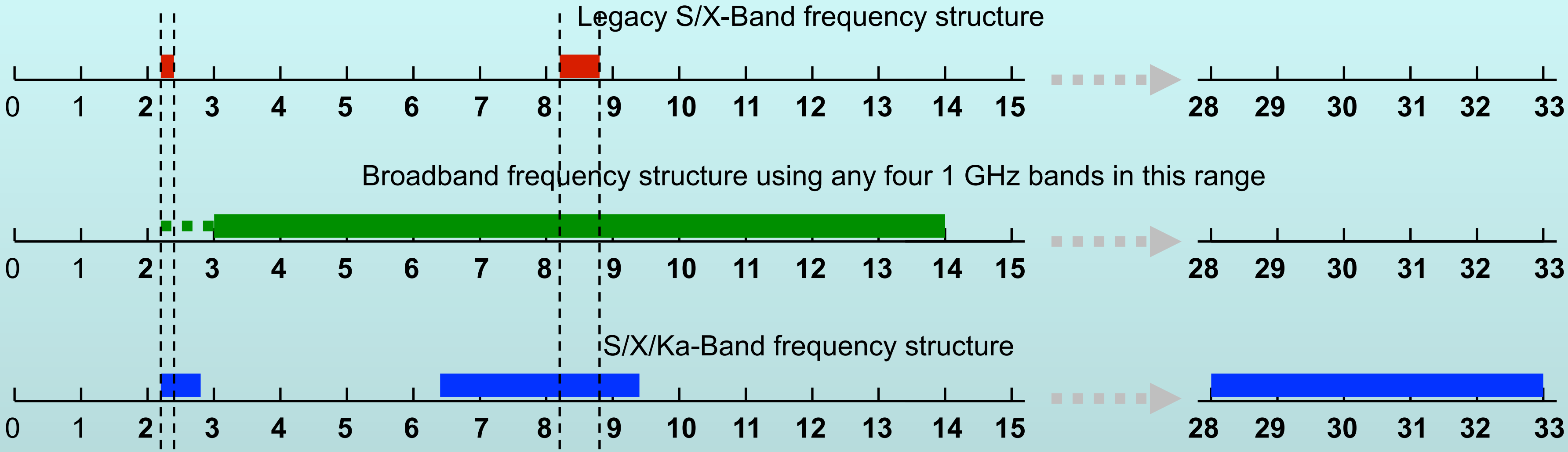
VGOS Technical

Challenges

Compliance with VGOS spec

- Input frequency range = 2.3 - 14 GHz, dual polarization
  - *** Many stations have difficulty with 2.3 – 3 GHz due to RFI ***
- Four 1 GHz bands that can each be placed anywhere in the input range
  - Some stations can only achieve 512 MHz bandwidths
- Channelization of bands into nominally 32 MHz channels
  - Some DBEs use a single monolithic band covering the full 1024 MHz band
- 16 Gbps instantaneous acquisition rate
  - Tests now use only 8 Gbps
  - 16 Gbps will at least initially require the use of burst RAM and writing to disk slower during slews
  - May eventually use 32 Gbps
- Some e-Transfer to achieve initial results within 24-hours.
- Calibration required
  - Phase, Cable, Amplitude

Continuity of Broadband with Legacy Network



Possible methods for tying new Broadband antennas to the legacy S/X network

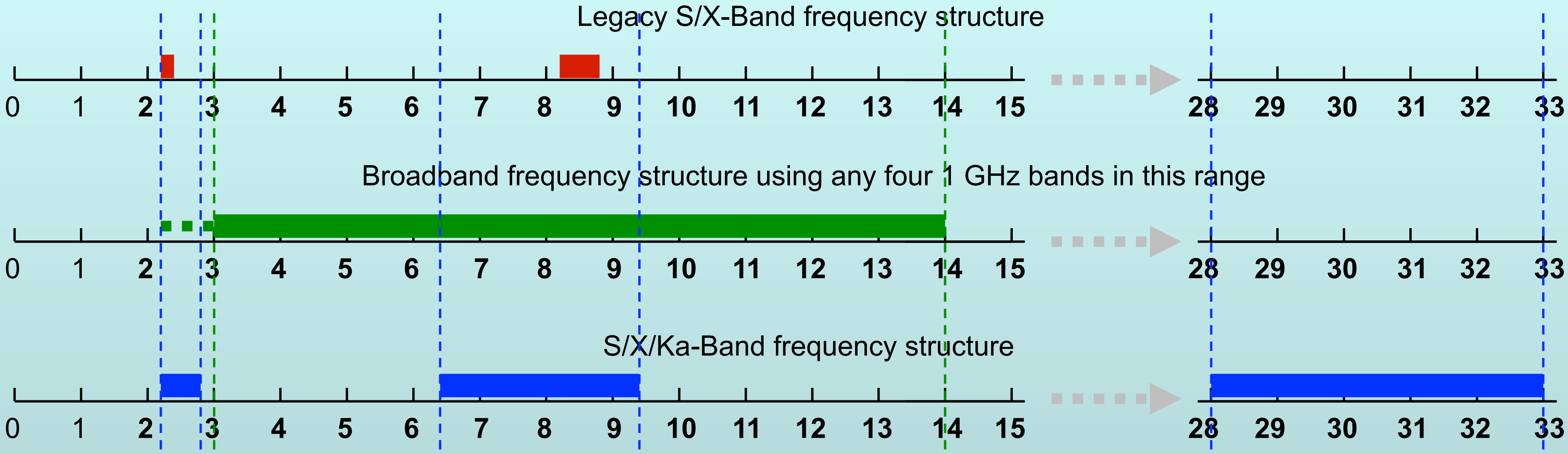
1.
If the **Broadband feed covers the full 2.3 – 14 GHZ frequency range**, then **observations can be taken directly with the legacy S/X network in “mixed” mode**.

2.
If 2.3 – 3 GHz of the Broadband range cannot be used due to RFI, but **a legacy S/X or S/X/Ka feed is available**, then **feeds can be swap periodically to observe with the legacy S/X network**.

3.
If 2.3 – 3 GHz of the Broadband range cannot be used due to RFI, but **the broadband antenna is co-located with a legacy S/X antenna**, then **local ties can be established at X-band only**.

4.
If **all else fails**, then **indirect ties can be established by observing with Broadband antennas that have already been tied to the legacy S/X network.**

Compatibility of Band Structures



1.
Broadband works best if four bands are optimally placed across the full 2.3 (or 3) – 14 GHz broadband range

2.
S/X/Ka works best if the full X and Ka band regions are used.

3.
If only the overlap regions are used, what remains is essentially an expanded S/X.

4.
If Broadband stations cannot use 2.3 – 3 GHz because of RFI, then the hybrid system has no S-band and hence no Ionosphere correction.

- In general Broadband and S/X/Ka-band systems do not work well together.
- The best results will be produced when all VGOS antennas observe in a single unified network with all elements using the same band structure .
- Broadband remains the standard for VGOS (unless it is proven not to work).

Compatibility (i.e. Interoperability) of Systems

- Many different versions of subsystems exist, e.g.
  - RDBE vs DBBC, plus many others
- Interoperability can fail for a number of reasons, e.g.
  - Incompatible LO parameters
  - Misunderstood sideband definitions
  - Misunderstood format definitions
  - Misunderstood bit encoding
  - Unaccounted system delays
- Testing is required to reveal interoperability issues
  - … but most can be corrected easily
- Many can be corrected in the correlator, but this adds to
  - Complexity of setting up correlator runs
  - Proliferation of correlator ‘mixed mode’ features

Network ***Connections*** (e-Transfer, e-VLBI, MCI)

e-Transfer requirements for 24/7 operation of a 20-station VGOS network

	Required (Gbps)	Existing (Gbps)
Station	5	1 – 10
Correlator	100	1 - 20

- The major network bottleneck for VGOS is at the correlators where data rates of ~100 Gbps may be required by 2020.
- Disk shipment will continue to play a significant role into the foreseeable future.
  - It is recommended that all stations maintain a capability for removable media.

Correlation

- The number of correlator cores is adequate for the immediate future (but eventaully more are needed).
- The capability to correlate and fringe both polarizations and all bands simultaneously to give single values for ionosphere and group delays has been implemented.
- Efficiency of gathering data into internal correlator storage is improving but could still be significantly better.
- Significant hand work is still required to set up correlator jobs (since VEX2 had not yet been applied to automate correlator setup).
- VGOS correlator processes need to be exported to other correlators so experience can be gained with broadband (but not ready yet).
- Network bandwidth at correlators for VGOS e-Transfer and e-VLBI remains a challenge with no immediate prospect for significant improvement
  - Should the concept of ‘distributed’ correlation be revisited.

Monitor/***Control*** Interface

- Automation is a priority for VGOS.
- Many parameters need to be acquired to evaluate the health of the station and the success of the observation, e.g.
  - Wx, calibrations, voltages, temps, …
- To be useful the data should be
  - logged 24/7
  - easily available via Internet.
  - Conveniently distilled into succinct status reports and alarms
  - Meaningfully displayed at the control centre
- Significant work has been done on this (Alexander Niedhardt and Chris Beaudoin) and a few solutions are being considered.
- A coherent (standardized) plan needs to be put in place so that all stations can be conveniently monitored from any control centre.

Conclusions

Daily VGOS observations will likely be delayed about 1 year relative to the VGOS Observing Plan.

Some challenges lie ahead but none appear to be insurmountable.

All the right steps are being taken to achieve daily VGOS operations as soon as possible, e.g.

- Efficient operational processes are being put in place.
- VGOS signal chains are being established at a number of sites.

Within the next year or so we should see the first significant global scale VGOS observations.