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Pilot multi-messenger event handling

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Abstract

As a final deliverable for the work on alert handling mechanisms a demonstration was performed where a potential gravitational wave event was followed up in a coordinated fashion by both the LOFAR and e-EVN arrays at radio wavelengths. This demonstration was largely successful. A simulated (short) GRB event from Swift was inserted in an extended triggerLOFAR setup and schedules were submitted to both LOFAR and the e-EVN for automatic followup. This automatic trigger was successfully observed by the e-EVN. Due to technical issues the LOFAR array did not observe at the same time. However that part of the system has been demonstrated to work many times in the recent past. This document provides a description of that demonstration, including the software that was used.

I. COPYRIGHT NOTICE

II. DELIVERY SLIP

	Name	Partner/WP	Date
From		JIVE / WP5	
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III. DOCUMENT LOG

Issue	Date	Comment	Author/Partner
1	2019-04-29	first draft	Mark Kettenis / JIVE
2	2019-06-21	updated draft	Mark Kettenis / JIVE
3	2019-06-25	Final	Mark Kettenis / JIVE

IV.   APPLICATION AREA

This document is a formal deliverable for the GA of the project, applicable to all members of the ASTERICS project, beneficiaries and third parties, as well as its collaborating projects.

V.   TERMINOLOGY

A complete project glossary is provided at the following page:
http://www.asterics2020.eu/glossary/

VI.   PROJECT SUMMARY

ASTERICS (Astronomy ESFRI & Research Infrastructure Cluster) aims to address the cross-cutting synergies and common challenges shared by the various Astronomy ESFRI facilities (SKA, CTA, KM3Net & E-ELT). It brings together for the first time, the astronomy, astrophysics and particle astrophysics communities, in addition to other related research infrastructures. The major objectives of ASTERICS are to support and accelerate the implementation of the ESFRI telescopes, to enhance their performance beyond the current state-of-the-art, and to see them interoperate as an integrated, multi-wavelength and multi-messenger facility. An important focal point is the management, processing and scientific exploitation of the huge datasets the ESFRI facilities will generate. ASTERICS will seek solutions to these problems outside of the traditional channels by directly engaging and collaborating with industry and specialised SMEs. The various ESFRI pathfinders and precursors will present the perfect proving ground for new methodologies and prototype systems. In addition, ASTERICS will enable astronomers from across the member states to have broad access to the reduced data products of the ESFRI telescopes via a seamless interface to the Virtual Observatory framework. This will massively increase the scientific impact of the telescopes, and greatly encourage use (and re-use) of the data in new and novel ways, typically not foreseen in the original proposals. By demonstrating cross-facility synchronicity, and by harmonising various policy aspects, ASTERICS will realise a distributed and interoperable approach that ushers in a new multi-messenger era for astronomy. Through an active dissemination programme, including direct engagement with all relevant stakeholders, and via the development of citizen

scientist mass participation experiments, ASTERICS has the ambition to be a flagship for the scientific, industrial and societal impact ESFRI projects can deliver.

VII.   EXECUTIVE SUMMARY

Automated follow-up observations are essential for modern multi-messenger astronomy. For this purpose, the ASTERICS project has developed several software tools to facilitate such follow-up observations. This document describes a demo that was done in order to demonstrate some of these software tools by doing a coordinated follow-up of a simulated GRB detection by the LOFAR and e-EVN radio telescopes.

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1. Introduction

An important aspect of modern multi-messenger astronomy is the follow-up of events detected by one instrument by other instruments looking at different parts of the EM spectrum and other messengers. A prime example of this is the detection of gravitational waves resulting from the merger of two neutron stars in event GW170817. As an electromagnetic counterpart was expected for such an event, this detection was followed-up at many observatories across the EM spectrum (eventually) leading to a precise localization of the event through VLBI observations.

In the case of GW170817 the afterglow of the event has been visible for a long time, peaking days after the event at some wavelengths. But for other events there might be a much shorter time-window in which the event is observable. In those cases, a (largely) automated follow-up approach would help tremendously. Within the ASTERICS project we have developed tools to facilitate such an automated follow-up. In order to show the functionality of these tools we performed a demonstration where we simulated the follow-up of a gravitational wave detection in the form of a detection of a short GRB by NASA's Niel Gehrels Swift Observatory by the LOFAR and e-EVN radio telescopes.

2. LOFAR follow-up

LOFAR is a low-frequency radio telescope in the North-East of the Netherlands, with additional stations in other European countries. It has a relatively large point of view and no movable parts, which means that it can be pointed into a particular direction almost instantly. This makes it a very suitable telescope for follow-up of multi-messenger events, even when these events are not localized very precisely yet.

The triggerLOFAR[1] software was developed by Rowlinson and collaborators to respond to short GRB triggers from Swift with LOFAR. The software is used in an active GW follow-up programme running on the LOFAR telescope. The software listens for VOEvents using to comet VOEvent broker and uses the 4PiSky tools to extract information from the event to make a decision on whether the event is interesting enough to trigger a LOFAR observation. If an observation is triggered, the software creates a trigger request in XML format for the LOFAR responsive telescope system based on a template. This is done by replacing a limited number of placeholder elements, such as positions of the target and calibrators, with information extracted from the event or calculated based on the target position. This request is then

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[1] https://github.com/AntoniaR/triggerLOFAR

submitted to the LOFAR responsive telescope system for immediate observation. The LOFAR responsive telescope system is described extensively in ASTERICS deliverable D5.10 "Software components multi-messenger event handling".

For this demonstration the triggerLOFAR software was extended to submit a trigger to the EVN in addition to the triggering LOFAR through the responsive telescope interface. Since the code to trigger LOFAR can block for some time whereas the code to trigger the EVN is quite fast, the code that calls into the EVN trigger code was inserted before the code that submits the LOFAR trigger to make sure that the asynchronous process where the operators at the stations are notified and confirm a pending trigger as early as possible.

3. VLBI follow-up

The field-of-view of a traditional VLBI observation is small. This means that an accurate position of a target is needed for a successful follow-up observation. Unfortunately, most instruments that are able to detect events for which a follow-up is desired (e.g. LIGO/Virgo, Swift, Fermi) do not provide such accuracy. In the past most VLBI follow-up of transients has been done after detection by radio interferometry, e.g. using the VLA or WSRT. Even a detection by LOFAR is unlikely to provide the necessary accuracy.

In principle the field of view of a VLBI observation is limited only by the field of view of the individual telescopes in the VLBI array. The final field of view is determined by time and bandwidth smearing which are determined by the integration time and spectral resolution used in the correlation. Short integration times and high spectral resolution reduce the amount of smearing and increase the field of view. But as a result, it also increases the size of the output data, which in turn increases the amount of computation needed to create an image. It also complicates the analysis of such an image.

Fortunately, there is an alternative approach. Modern VLBI (software) correlators implement a multiple phase center correlation feature. Using this feature, it is possible to pick a number of locations within the field of view of the array and simultaneously correlate with reasonable time and spectral resolution for each of these locations. This is done by doing the correlation with full time and spectral resolution, applying an appropriate phase shift for each location of interest. If we can create a list of potential targets that match the uncertainty in the detection of the transient event, we can use this feature and produce images at VLBI resolution for each of these targets. Since the overhead for each additional phase center is relatively small, the number of these targets can be fairly large (of the order of 100).
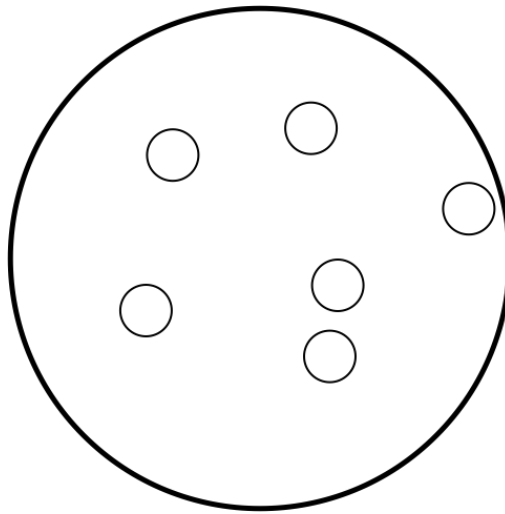
Figure 1: Illustration of the Multiple Phase Center correlation functionality. The large circle represents the field of view of an individual VLBI telescope. The smaller circles represent the field of view of the phase centers produced by the correlator. The correlator creates a separate data set for each phase center.

For this demo we developed software that creates a multiple phase center correlation schedule. The software picks these targets by cross-correlating the position from the event with a catalog of radio sources. This is done by using the astroquery package[2]. For this particular demonstration a catalog of NRAO observations was chosen, but this can be easily changed by picking any of the other catalogues supported by astroquery.

The code also automatically picks a suitable calibrator from the SCHED VLBI calibrator catalogue. Such a calibrator is needed to successfully calibrate the data for instrumental and atmospheric effects. Without this calibration, imaging data from a VLBI observation will almost never be possible.

The VLBI schedule for the trigger observation is created using pySCHED[3]. pySCHED is a derivative of the SCHED VLBI scheduling software that has been developed over the past decades by Craig Walker at NRAO with the help of a small team of astronomers and software developers across the globe. This software is the de-facto standard for creating schedules of astronomical VLBI observations. The SCHED software has been developed in Fortran. Since the pool of Fortran developers in the community is dwindling and re-usability of the SCHED Fortran code is somewhat limited, a project was started to refactor SCHED using Python. The existing Fortran code was wrapped (using Numpy's f2py) such that it can be called from

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[2] https://astroquery.readthedocs.io

[3] https://github.com/jive-vlbi/sched

Python. The top-level code was rewritten in Python using existing Python code to parse the "keyin" syntax used to drive SCHED. This approach allows gradual replacement of existing FORTRAN functionality (e.g. the code that checks the telescope backend configuration) or add new functionality (e.g. VEX2 output) in Python. The main benefit for this demonstration is that pySCHED over SCHED makes it possible to create schedules for the e-EVN that work without additional manual tweaks. For this purpose, a small Python module was developed that creates a schedule based on a set of input parameters. This module then populates a "keyin" input file that drives pySCHED to create the schedule. Since SCHED (and therefore pySCHED) already does all the relevant constraint checking, we did not have to replicate logic that checks whether a target is observable in our code. Schedule generation will simply fail if not enough telescopes can observe the source and the trigger will not be submitted to the system. The module also takes care of producing an augmented version of the schedule for the correlator that includes additional phase centers and clock offsets.

The schedule generation is driven by a triggerEVN script that is called directly from the modified triggerLOFAR code. This schedule is then submitted to the e-EVN through the existing REST interface. The correlator schedule is also automatically inserted in the database at the correlator such that the correlator can be easily started.
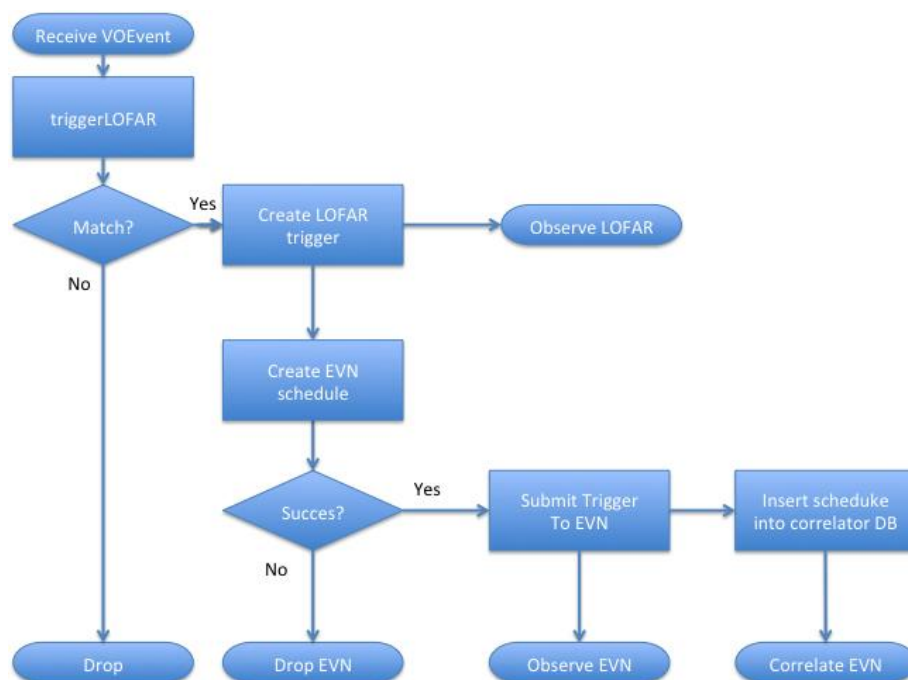
Figure 2: High-level flowchart of the event handling

4. Demonstration

The demonstration took place on April 29th 2019. Three EVN telescopes participated in this demonstration; the 25m telescope at Onsala Space Observatory in Sweden (On), the 26m telescope at Hartebeesthoek in South-Africa (Hh) and one of the 25m telescopes of the Westerbork Synthesesis Radio Telescope in the Netherlands (Wb). Figure 3 shows where these telescopes (including the core of the LOFAR telescope) are located. The presence of the Hartebeesthoek telescope in the array means that this demo included some long baselines. As a result, the scheduling constraints for the array can be considered to be representative for a typical EVN VLBI observation.

Image by Paul Boven (boven@jive.eu). Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).
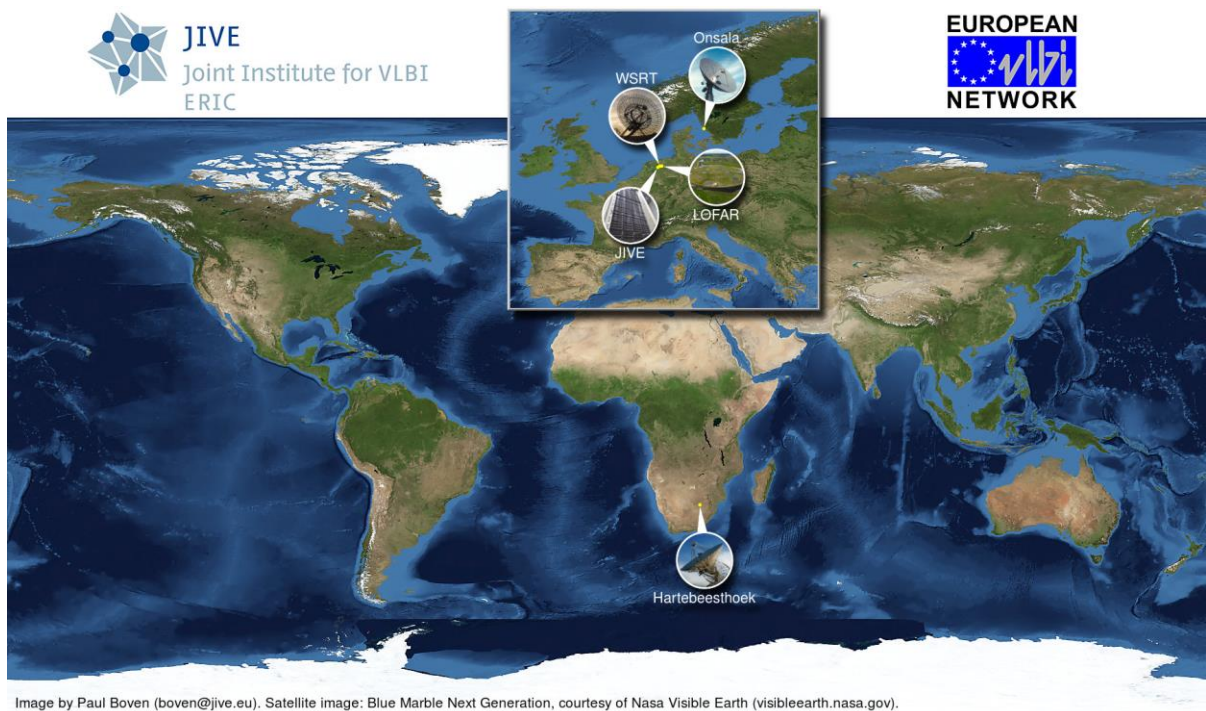
Figure 3: LOFAR and e-EVN telescopes used for this demonstration.

Automatic triggers on the e-EVN operate on the basis that they will interrupt an already running e-VLBI observation. This avoids having to reserve recording media for these observations. It also means the results of the correlation are available on a much shorter timescale than with regular VLBI as there are no media that need to be shipped to the correlator. The raw correlated visibilities are available within minutes (i.e. the time it takes for the data to pass through the correlator and land on disk). And fully pipelined calibrated visibility data can be made available on the timescale of a day. The downside is that

recorrelation of the data isn't possible. So, if for example the position associated with the event is refined at a later time there is no way to go back to the original voltage data and recorrelate with the updated position. This could be avoided by simultaneously recording the voltage data at the correlator during the observation. This does require allocating recording media for the triggered observation, but the data can be erased quickly if further correlation is not needed.

For the demonstration, a regular e-VLBI experiment schedule was created. The name of this experiment was FR059 and it simulated a phase-reference observation of a bright calibrator and a weaker target source. The schedule was created using pySCHED, driving it in much the same way as the automatic trigger processing software would do. The presence of a bright calibrator in the schedule made it easy to verify that the VLBI array was operating correctly before receiving the automatic trigger. This schedule can be found in VEX format in appendix B.

For the automatic trigger, a target was selected that was visible to all telescopes of the VLBI array that participated in the demonstration. The position of this target was inserted into an existing VOEvent from Swift. The observation time in the VOEvent was adjusted as well such that the trigger would not be rejected by the automatic trigger processing software based on the fact that it happened too far in the past.

The FR059 schedule was started shortly after 07:00 UTC. Data was received from all three participating EVN telescopes. Unfortunately, fringes were only detected between Hh and On. It is not entirely clear what the problem with Wb was. There have been some stability issues with the hydrogen maser at Wb in the timeframe of the demonstration, which remains a likely cause for the lack of fringes. We were not able to resolve the (presumable) technical problem with Wb before the event was inserted into the system.

The simulated GRB VOEvent was inserted into the system at 10:46 UTC and resulted in a valid LOFAR responsive telescope trigger request and a valid trigger VLBI schedule. This trigger schedule included 4 additional phase centers in addition to the target at the position indicated in the event. The generated LOFAR XML file can be found in appendix A. The generated VLBI schedule can be found in appendix C.

The trigger schedule with experiment name TR001 was inserted into the EVN automatic trigger system at 10:47:55 UTC. The trigger was detected by the station module at On at 10:48:13 UTC, and by the station module at Hh at 10:48:30 UTC. The operator at Hh acknowledged the trigger at 10:49:13 UTC. The operator at On didn't acknowledge the trigger until 10:55:44 UTC. Triggers need to be acknowledged by the individual telescopes for safety reasons. Correlator staff restarted correlation at 10:50 UTC and first fringes were seen shortly after 10:58 indicating that both stations were observing the calibrator. The real proof of the pudding was the fact that the fringe disappeared when observing the target, which indicates that the telescopes were indeed observing the TR001 schedule instead of the FR059 schedule as the target is expected to be too weak to be detected by now.
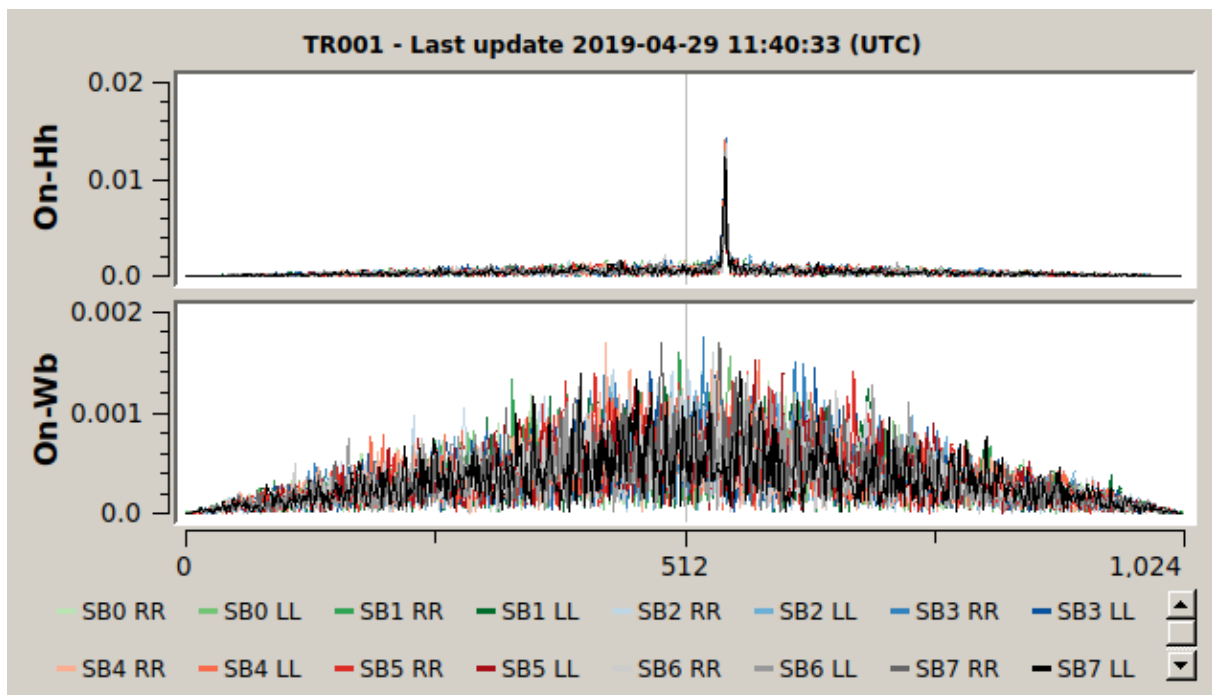
Figure 4: Fringe plot showing the detection of the calibrator source in the trigger schedule.

At the end of the TR001 schedule, the telescopes switched back to observing the FR059 schedule automatically.

The request to the LOFAR responsive telescope system failed after a timeout. This was caused by the fact that some of LOFAR online systems were still down after a failed software upgrade in the week before.

5. Challenges

The transition from Python 2 to Python 3 that is happening in many software communities is causing some challenges. The pySCHED code is written for Python 3 and the latest release of the Astropy project is also only available for Python 3. On the other hand, code that has a longer history, such as the 4PiSky tools used by triggerLOFAR and the EVN automatic trigger code is only available for Python 2. As a result, combining all code into a single Python program was not possible. To circumvent this issue, the pySCHED code that generated the VLBI schedule was called as a separate program.

Finding a timeslot for the demonstration proved to be difficult. To minimize the impact on running science observations we looked for a timeslot outside of the regular e-EVN (and EVN) observation schedule. This was complicated by the fact that a regular (non-EVLBI) observing session took place from February 21 - March 14. Time slots with no or with movable LOFAR science observations were found before and after that block but became unavailable before

the demonstration could take place, partly because of a time-critical observation campaign. Normally, the scientifically higher ranked project would be observed in case of a LOFAR trigger, but commissioning this mode was lower priority, so we decided to postpone the test. Ultimately a slot was found and commissioning time was approved for the 29th of April, just before the end of the ASTERICS project.

Unfortunately, a LOFAR software update during the week before the demonstration did not go as well as planned. In particular, the LOFAR responsive telescope functionality was affected. Eventually this software update had to be rolled back, but that did not happen until the week after the slot reserved for the demonstration. As a result, this demonstration did not result in an actual LOFAR observation.

6. Conclusion

Automatic triggers with the e-EVN are possible and while the response time is longer than for a centrally managed array like LOFAR it is possible to do a follow-up of an event within 15 minutes. While this is longer than the advertised response of the LOFAR responsive telescope system (which is 5 minutes) it is certainly good enough to guarantee coincidental observing of the two instruments.

While it could be argued that planning a triggered observation like we did in this demonstration is not very realistic, the problems that we encountered in doing so are somewhat representative for follow-ups of real events as well. The fact that we had to abandon two earlier scheduled timeslots before even starting the demonstration illustrates that the chances of a successful coordinated observation that involves these two observatories remains small. However, if the potential science impact of such an observation is high it may very well be worth it.

Acknowledgements

A.   Appendix: LOFAR trigger request

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<station> <name>CS001</name> </station>
        <station> <name>CS002</name> </station>
        <station> <name>CS003</name> </station>
        <station> <name>CS004</name> </station>
        <station> <name>CS005</name> </station>
        <station> <name>CS006</name> </station>
        <station> <name>CS007</name> </station>
        <station> <name>CS011</name> </station>
        <station> <name>CS013</name> </station>
        <station> <name>CS017</name> </station>
        <station> <name>CS021</name> </station>
        <station> <name>CS024</name> </station>
        <station> <name>CS026</name> </station>
        <station> <name>CS028</name> </station>
        <station> <name>CS030</name> </station>
        <station> <name>CS031</name> </station>
        <station> <name>CS032</name> </station>
        <station> <name>CS103</name> </station>
        <station> <name>CS201</name> </station>
        <station> <name>CS301</name> </station>
        <station> <name>CS302</name> </station>
        <station> <name>CS401</name> </station>
        <station> <name>CS501</name> </station>
        <station> <name>RS106</name> </station>
        <station> <name>RS205</name> </station>
        <station> <name>RS208</name> </station>
        <station> <name>RS305</name> </station>
        <station> <name>RS306</name> </station>
        <station> <name>RS307</name> </station>
        <station> <name>RS406</name> </station>
        <station> <name>RS409</name> </station>
        <station> <name>RS503</name> </station>
        <station> <name>RS508</name> </station>
        <station> <name>RS509</name> </station>
            </stations>
 </stationSelection>
</stationSelectionSpecification>
<timeWindowSpecification>
 <timeFrame>UT</timeFrame>
<minStartTime>2019-04-29T11:03:28</minStartTime>
        <maxEndTime>2019-04-29T11:21:28</maxEndTime>
 <duration>
        <duration>PT600S</duration>
 </duration>
</timeWindowSpecification>
</observation>
<status>approved</status>
<qualityOfService>LATENCY</qualityOfService>
<priority>1005</priority>
<triggerId>
 <source>MoM</source>
 <identifier>1</identifier>
</triggerId>
</activity>

<!-- SAP 0 -->
```

```xml
<activity>
  <temporaryIdentifier>
    <source>0</source>
    <identifier>310</identifier>
    <description>0</description>
  </temporaryIdentifier>
  <measurement xsi:type="base:SAPMeasurement">
    <name>Calibrator</name>
    <description>Calibrator</description>
    <ra>24.422071</ra>
    <dec>33.159755</dec>
    <equinox>J2000</equinox>
    <subbandsSpecification>
      <subbands>104..347</subbands>
    </subbandsSpecification>
    <tiedArrayBeams>
      <nrTabRings>0</nrTabRings>
      <!--<tabRingSize></tabRingSize>-->
      <tiedArrayBeamList/>
    </tiedArrayBeams>
    <measurementType>Target</measurementType>
  </measurement>
  <status>approved</status>
  <qualityOfService>LATENCY</qualityOfService>
  <priority>1010</priority>
  <triggerId>
    <source>MoM</source>
    <identifier>1</identifier>
  </triggerId>
</activity>

<!-- Calibrator Averaging Pipeline -->
<activity>
  <temporaryIdentifier>
    <source>0</source>
    <identifier>211</identifier>
    <description>0</description>
  </temporaryIdentifier>
  <pipeline xsi:type="base:AveragingPipeline">
    <name>Calibrator/1.0/TP</name>
    <description>Calibrator/1.0/TP (Preprocessing)</description>
    <processingCluster>
      <name>CEP4</name>
      <partition>cpu</partition>
      <numberOfTasks>122</numberOfTasks>
      <minRAMPerTask unit="byte">1000000000</minRAMPerTask>
      <minScratchPerTask unit="byte">100000000</minScratchPerTask>
      <maxDurationPerTask>PT600S</maxDurationPerTask>
      <numberOfCoresPerTask>2</numberOfCoresPerTask>
      <runSimultaneous>true</runSimultaneous>
    </processingCluster>
    <defaultTemplate>Preprocessing Pipeline</defaultTemplate>
    <demixingParameters>
      <averagingFreqStep>16</averagingFreqStep>
      <averagingTimeStep>1</averagingTimeStep>
      <demixFreqStep>64</demixFreqStep>
      <demixTimeStep>10</demixTimeStep>
      <demixAlways/>
      <demixIfNeeded/>
      <ignoreTarget>false</ignoreTarget>
    </demixingParameters>
    <flaggingStrategy>HBAdefault</flaggingStrategy>
  </pipeline>
  <status>approved</status>
  <qualityOfService>LATENCY</qualityOfService>
```

```
    <priority>1010</priority>
    <triggerId>
      <source>MoM</source>
      <identifier>1</identifier>
    </triggerId>
  </activity>



  <!-- SAP 1 data products -->
  <entity>
    <temporaryIdentifier>
      <source>0</source>
      <identifier>401</identifier>
    </temporaryIdentifier>
    <dataproductType>UVDataProduct</dataproductType>
    <storageCluster>
      <name>CEP4</name>
      <partition>/data/projects/</partition>
    </storageCluster>
  </entity>

  <!-- Calibrator measurement dataproducts -->
  <entity>
    <temporaryIdentifier>
      <source>0</source>
      <identifier>410</identifier>
    </temporaryIdentifier>
    <dataproductType>UVDataProduct</dataproductType>
    <storageCluster>
      <name>CEP4</name>
      <partition>/data/projects/</partition>
    </storageCluster>
  </entity>

  <!-- Calibrator Pipeline dataproducts -->
  <entity>
    <temporaryIdentifier>
      <source>0</source>
      <identifier>411</identifier>
    </temporaryIdentifier>
    <dataproductType>UVDataProduct</dataproductType>
    <storageCluster>
      <name>CEP4</name>
      <partition>/data/projects/</partition>
    </storageCluster>
  </entity>

  <!-- Target Pipeline dataproducts -->
  <entity>
    <temporaryIdentifier>
      <source>0</source>
      <identifier>402</identifier>
    </temporaryIdentifier>
    <dataproductType>UVDataProduct</dataproductType>
    <storageCluster>
      <name>CEP4</name>
      <partition>/data/projects/</partition>
    </storageCluster>
  </entity>

  <!-- folder 101 is child of folder 100 -->
  <relation xsi:type="spec:ChildRelation">
    <parent>
      <source>0</source>
```

```xml
    <identifier>100</identifier>
   </parent>
   <child>
    <source>0</source>
    <identifier>101</identifier>
   </child>
   <type>folder-folder</type>
  </relation>

  <!-- folder 110 is child of folder 100 -->
  <relation xsi:type="spec:ChildRelation">
   <parent>
    <source>0</source>
    <identifier>100</identifier>
   </parent>
   <child>
    <source>0</source>
    <identifier>110</identifier>
   </child>
   <type>folder-folder</type>
  </relation>

  <!-- observation 200 is child of folder 101 -->
  <relation xsi:type="spec:ChildRelation">
   <parent>
    <source>0</source>
    <identifier>101</identifier>
   </parent>
   <child>
    <source>0</source>
    <identifier>200</identifier>
   </child>
   <type>folder-activity</type>
  </relation>


  <!-- measurement 301 is a child of observation 200 -->
  <relation xsi:type="spec:ChildRelation">
   <parent>
    <source>0</source>
    <identifier>200</identifier>
    <description>0</description>
   </parent>
   <child>
    <source>0</source>
    <identifier>301</identifier>
    <description>0</description>
   </child>
   <type>observation-measurement</type>
  </relation>

  <!-- observation 210 is child of folder 110 -->
  <relation xsi:type="spec:ChildRelation">
   <parent>
    <source>0</source>
    <identifier>110</identifier>
   </parent>
   <child>
    <source>0</source>
    <identifier>210</identifier>
   </child>
   <type>folder-activity</type>
  </relation>
```

```
<!-- measurements 310 is a child of observation 210 -->
<relation xsi:type="spec:ChildRelation">
 <parent>
  <source>0</source>
  <identifier>210</identifier>
 </parent>
 <child>
  <source>0</source>
  <identifier>310</identifier>
 </child>
 <type>observation-measurement</type>
</relation>




<!-- dataproducts 401 are output of measurement 301 -->
<relation xsi:type="spec:ActivityEntityRelation">
 <entity>
  <source>0</source>
  <identifier>401</identifier>
 </entity>
 <activity>
  <source>0</source>
  <identifier>301</identifier>
 </activity>
 <type>producer</type>
</relation>

<!-- dataproducts 410 are output of measurement 310 -->
<relation xsi:type="spec:ActivityEntityRelation">
 <entity>
  <source>0</source>
  <identifier>410</identifier>
 </entity>
 <activity>
  <source>0</source>
  <identifier>310</identifier>
 </activity>
 <type>producer</type>
</relation>




<!-- Calibrator measurement is the calibrator for SAP 1 -->
<relation xsi:type="spec:TwinRelation">
 <first>
  <source>0</source>
  <identifier>310</identifier>
 </first>
 <second>
  <source>0</source>
  <identifier>301</identifier>
 </second>
 <type>calibrator-target</type>
</relation>

<!-- dataproducts 401 are input for pipeline 201 -->
<relation xsi:type="spec:ActivityEntityRelation">
 <entity>
  <source>0</source>
  <identifier>401</identifier>
 </entity>
 <activity>
  <source>0</source>
  <identifier>201</identifier>
```

```
    </activity>
    <type>user</type>
  </relation>

  <!-- dataproducts 402 are output of pipeline 201 -->
  <relation xsi:type="spec:ActivityEntityRelation">
    <entity>
      <source>0</source>
      <identifier>402</identifier>
    </entity>
    <activity>
      <source>0</source>
      <identifier>201</identifier>
    </activity>
    <type>producer</type>
  </relation>

  <!-- pipeline 201 is child of folder 101 -->
  <relation xsi:type="spec:ChildRelation">
    <parent>
      <source>0</source>
      <identifier>101</identifier>
    </parent>
    <child>
      <source>0</source>
      <identifier>201</identifier>
    </child>
    <type>folder-activity</type>
  </relation>

  <!-- dataproducts 410 are input for pipeline 211 -->
  <relation xsi:type="spec:ActivityEntityRelation">
    <entity>
      <source>0</source>
      <identifier>410</identifier>
    </entity>
    <activity>
      <source>0</source>
      <identifier>211</identifier>
    </activity>
    <type>user</type>
  </relation>

  <!-- pipeline 211 is child of folder 110 -->
  <relation xsi:type="spec:ChildRelation">
    <parent>
      <source>0</source>
      <identifier>110</identifier>
    </parent>
    <child>
      <source>0</source>
      <identifier>211</identifier>
    </child>
    <type>folder-activity</type>
  </relation>

  <!-- dataproducts 411 are output of pipeline 211 -->
  <relation xsi:type="spec:ActivityEntityRelation">
    <entity>
      <source>0</source>
      <identifier>411</identifier>
    </entity>
    <activity>
      <source>0</source>
      <identifier>211</identifier>
```

```
                    </activity>
                  <type>producer</type>
                </relation>
        </specification>
        <generatorName>Jan David Mol</generatorName>
        <generatorVersion>0.0</generatorVersion>
</trigger:trigger>
```

B. Appendix: FR059 schedule

```
VEX_rev = 1.5;
*   VEX/SCHED:  1.5.87
*   Other versions: Sched: 11.5  Plot: 1.06  JPL-ephem: 1.01
*------------------------------------------------------------------------------
$GLOBAL;
    ref $EXPER = FR059;
    ref $EOP = EOP118;
*                               +------------+
*                PI revision number:    |   1.0000  |
*                               +------------+
*   mode:     VLBA/MKIV
*------------------------------------------------------------------------------
$EXPER;
*
def FR059;
    exper_name = FR059;
    exper_description = "FR059";
    PI_name = "Automated Trigger";
    PI_email = jops@jive.eu;
*   address:   JIVE, Radiosterrenwacht Dwingeloo
*          Postbus 2, 7990 AA Dwingeloo
*          the Netherlands
*
*   phone:    +31 521 595 530
*   during obs:
*   fax:
*
*   year, doy: 2019, 119
*   date    : Mon 29 Apr 2019
*   MJD     : 58602
    exper_nominal_start=2019y119d07h00m00s;
    exper_nominal_stop=2019y119d12h00m00s;
*
    target_correlator = JIVE;
*
*   integr_time   :    2.000 s
*   number_channels:   128
*   number_antenna :  8
*   cross_polarize : Yes
*   weight_func    : UNIFORM
*   distrib_medium : DAT
*   distrib_format : FITS
*   source_pos_cat : STANDARD
*   distribute_to  :
*            Jops
*            JIVE, Radiosterrenwacht Dwingeloo
*            Postbus 2, 7990 AA Dwingeloo
*            the Netherlands
*
enddef;
*------------------------------------------------------------------------------
$MODE;
*
def setup;
    ref $PROCEDURES = Mode_01;
    ref $FREQ = 4942.49MHz16x16MHz:On;
    ref $FREQ = 4942.49MHz16x16MHz#02:Wb:Hh;
    ref $IF = LO@4100MHzDPolNoTone:On;
    ref $IF = LO@4587MHzDPolNoTone:Wb;
    ref $IF = LO@4600MHzDPolNoTone:Hh;
    ref $BBC = 16BBCs:On;
    ref $BBC = 16BBCs#02:Wb:Hh;
```

```
      ref $TRACKS = VDIF.16Ch2bit1to1:On:Wb:Hh;
      ref $BITSTREAMS = HhBitstreams:Hh:Wb:On;
      ref $THREADS = HhThreads:Hh:Wb:On;
*     ref $HEAD_POS = DiskVoid <= obsolete definition
      ref $ROLL = NoRoll:On:Wb:Hh;
*     ref $PASS_ORDER = DiskVoid <= obsolete definition
      ref $PHASE_CAL_DETECT = NoDetect:On:Wb:Hh;
enddef;
*------------------------------------------------------------------------------
$STATION;
*
def On;
      ref $SITE = ONSALA85;
      ref $ANTENNA = ONSALA85;
      ref $DAS = FILA10G;
      ref $TAPELOG_OBS = ON;
      ref $CLOCK = ON;
enddef;
*
def Wb;
      ref $SITE = WSTRBORK;
      ref $ANTENNA = WSTRBORK;
      ref $DAS = FILA10G;
      ref $TAPELOG_OBS = WB;
      ref $CLOCK = WB;
enddef;
*
def Hh;
      ref $SITE = HART;
      ref $ANTENNA = HART;
      ref $DAS = FILA10G;
      ref $TAPELOG_OBS = HH;
      ref $CLOCK = HH;
enddef;
*------------------------------------------------------------------------------
$PROCEDURES;
*
def Mode_01;
      procedure_name_prefix =  "01";
      tape_change =  420 sec;
      headstack_motion =    6 sec;
      new_source_command =    5 sec;
      new_tape_setup =   20 sec;
      setup_always = on :  20 sec;
      parity_check = off : 100 sec;
      tape_prepass = off : 600 sec;
      preob_cal  = on :  10 sec : preob;
      midob_cal  = on :  15 sec : midob;
      postob_cal = on :   0 sec : postob;
enddef;
*------------------------------------------------------------------------------
$SITE;
*
def ONSALA85;
      site_type = fixed;
      site_name = ONSALA85;
      site_ID = On;
*     elev=   58.48 long=-011:55:04. lat= 57:23:35.1
*     site_position = 3370965.90900 m:  711466.19780 m: 5349664.19470 m;
      site_position = 3370965.80226 m:  711466.27515 m: 5349664.25660 m;
*     First line below is VEX standard format.  Use only when readers are ready.
*     site_position_epoch = 2013y001d;
enddef;
*
def WSTRBORK;
      site_type = fixed;
      site_name = WSTRBORK;
      site_ID = Wb;
*     elev=   71.21 long=-006:38:00. lat= 52:54:55.1
```

```
*    site_position = 3828445.65900 m:  445223.60000 m: 5064921.56800 m;
     site_position = 3828750.39487 m:  442589.59798 m: 5064921.76488 m;
*    First line below is VEX standard format.  Use only when readers are ready.
*    site_position_epoch = 1997y001d;
enddef;
*
def HART;
     site_type = fixed;
     site_name = HART;
     site_ID = Hh;
*    elev= 1415.71 long=-027:41:07. lat=-25:53:23.1
*    site_position = 5085442.76370 m: 2668263.79130 m:-2768696.75230 m;
     site_position = 5085442.75548 m: 2668263.91131 m:-2768696.64307 m;
*    First line below is VEX standard format.  Use only when readers are ready.
*    site_position_epoch = 2013y001d;
enddef;
*------------------------------------------------------------------------------
$ANTENNA;
*
def ONSALA85;
     axis_type = ha : dec;
     antenna_motion = dec :  14.7 deg/min :  5 sec;  *    0.052 deg/sec/sec
     antenna_motion = ha :  17.6 deg/min :  5 sec;  *    0.070 deg/sec/sec
     axis_offset = 2.15000 m;
enddef;
*
def WSTRBORK;
     axis_type = ha : dec;
     antenna_motion = dec :  18.0 deg/min : 10 sec;  *    0.100 deg/sec/sec
     antenna_motion = ha :  18.0 deg/min : 10 sec;  *    0.100 deg/sec/sec
     axis_offset = 4.95000 m;
enddef;
*
def HART;
     axis_type = ha : dec;
     antenna_motion = dec :  30.0 deg/min : 20 sec;  *    0.071 deg/sec/sec
     antenna_motion = ha :  30.0 deg/min : 20 sec;  *    0.071 deg/sec/sec
     axis_offset = 6.69440 m;
enddef;
*------------------------------------------------------------------------------
$DAS;
*
def 2DBBC+NONE<;
     record_transport_type = Mark5B;
     electronics_rack_type = DBBC;
     number_drives = 2;
     headstack = 1 :          : 0 ;
     headstack = 2 :          : 1 ;
     tape_motion = adaptive : 0 min: 0 min: 10 sec;
enddef;
*
def FILA10G;
     record_transport_type = None;
     electronics_rack_type = DBBC;
enddef;
*
*------------------------------------------------------------------------------
$SOURCE;
*
def J0019+2021;
     source_name = J0019+2021;
*    this source had calibrator code:
     ra = 00h19m37.8545000s; dec =  20d21'45.644700"; ref_coord_frame = J2000;
*    ra = 00h17m02.1195568s; dec =  20d05'06.807740"; ref_coord_frame = B1950;
*    ra = 00h20m36.0006219s; dec =  20d27'54.455670"; ref_coord_frame = Date;
enddef;
*
def PHASE_CENTER;
     source_name = PHASE_CENTER;
```

```
*    this source had calibrator code:
     ra = 00h19m37.8545000s; dec =  20d21'45.644600"; ref_coord_frame = J2000;
*    ra = 00h17m02.1195568s; dec =  20d05'06.807640"; ref_coord_frame = B1950;
*    ra = 00h20m36.0006219s; dec =  20d27'54.455570"; ref_coord_frame = Date;
enddef;
def 060912A;
     source_name = 060912A;
     ra = 00h21m08.143s; dec = 20d58'17.41"; ref_coord_frame = J2000;
enddef;
*---------------------------------------------------------------------------
$FREQ;
*
def 4942.49MHz16x16MHz;
* mode =  1    stations =On
     sample_rate =  32.000 Ms/sec;  * (2bits/sample)
     chan_def = :  4942.49 MHz : L :  16.00 MHz : &CH01 : &BBC01 : &NoCal; *Rcp
     chan_def = :  4942.49 MHz : L :  16.00 MHz : &CH02 : &BBC09 : &NoCal; *Lcp
     chan_def = :  4942.49 MHz : U :  16.00 MHz : &CH03 : &BBC01 : &NoCal; *Rcp
     chan_def = :  4942.49 MHz : U :  16.00 MHz : &CH04 : &BBC09 : &NoCal; *Lcp
     chan_def = :  4974.49 MHz : L :  16.00 MHz : &CH05 : &BBC02 : &NoCal; *Rcp
     chan_def = :  4974.49 MHz : L :  16.00 MHz : &CH06 : &BBC10 : &NoCal; *Lcp
     chan_def = :  4974.49 MHz : U :  16.00 MHz : &CH07 : &BBC02 : &NoCal; *Rcp
     chan_def = :  4974.49 MHz : U :  16.00 MHz : &CH08 : &BBC10 : &NoCal; *Lcp
     chan_def = :  5006.49 MHz : L :  16.00 MHz : &CH09 : &BBC03 : &NoCal; *Rcp
     chan_def = :  5006.49 MHz : L :  16.00 MHz : &CH10 : &BBC11 : &NoCal; *Lcp
     chan_def = :  5006.49 MHz : U :  16.00 MHz : &CH11 : &BBC03 : &NoCal; *Rcp
     chan_def = :  5006.49 MHz : U :  16.00 MHz : &CH12 : &BBC11 : &NoCal; *Lcp
     chan_def = :  5038.49 MHz : L :  16.00 MHz : &CH13 : &BBC04 : &NoCal; *Rcp
     chan_def = :  5038.49 MHz : L :  16.00 MHz : &CH14 : &BBC12 : &NoCal; *Lcp
     chan_def = :  5038.49 MHz : U :  16.00 MHz : &CH15 : &BBC04 : &NoCal; *Rcp
     chan_def = :  5038.49 MHz : U :  16.00 MHz : &CH16 : &BBC12 : &NoCal; *Lcp
enddef;
*
def 4942.49MHz16x16MHz#02;
* mode =  1    stations =Wb:Hh
     sample_rate =  32.000 Ms/sec;  * (2bits/sample)
     chan_def = :  4942.49 MHz : L :  16.00 MHz : &CH01 : &BBC01 : &NoCal; *Rcp
     chan_def = :  4942.49 MHz : L :  16.00 MHz : &CH02 : &BBC05 : &NoCal; *Lcp
     chan_def = :  4942.49 MHz : U :  16.00 MHz : &CH03 : &BBC01 : &NoCal; *Rcp
     chan_def = :  4942.49 MHz : U :  16.00 MHz : &CH04 : &BBC05 : &NoCal; *Lcp
     chan_def = :  4974.49 MHz : L :  16.00 MHz : &CH05 : &BBC02 : &NoCal; *Rcp
     chan_def = :  4974.49 MHz : L :  16.00 MHz : &CH06 : &BBC06 : &NoCal; *Lcp
     chan_def = :  4974.49 MHz : U :  16.00 MHz : &CH07 : &BBC02 : &NoCal; *Rcp
     chan_def = :  4974.49 MHz : U :  16.00 MHz : &CH08 : &BBC06 : &NoCal; *Lcp
     chan_def = :  5006.49 MHz : L :  16.00 MHz : &CH09 : &BBC03 : &NoCal; *Rcp
     chan_def = :  5006.49 MHz : L :  16.00 MHz : &CH10 : &BBC07 : &NoCal; *Lcp
     chan_def = :  5006.49 MHz : U :  16.00 MHz : &CH11 : &BBC03 : &NoCal; *Rcp
     chan_def = :  5006.49 MHz : U :  16.00 MHz : &CH12 : &BBC07 : &NoCal; *Lcp
     chan_def = :  5038.49 MHz : L :  16.00 MHz : &CH13 : &BBC04 : &NoCal; *Rcp
     chan_def = :  5038.49 MHz : L :  16.00 MHz : &CH14 : &BBC08 : &NoCal; *Lcp
     chan_def = :  5038.49 MHz : U :  16.00 MHz : &CH15 : &BBC04 : &NoCal; *Rcp
     chan_def = :  5038.49 MHz : U :  16.00 MHz : &CH16 : &BBC08 : &NoCal; *Lcp
enddef;
*---------------------------------------------------------------------------
$IF;
*
def LO@4100MHzDPolNoTone;
* mode =  1    stations =On
     if_def = &IF_A1 : A1 : R :  4100.00 MHz : U ; * PCall off!   0.0   0.0  NA     0 NA
     if_def = &IF_C1 : C1 : L :  4100.00 MHz : U ; * PCall off!   0.0   0.0  NA     0 NA
enddef;
*
def LO@4587MHzDPolNoTone;
* mode =  1    stations =Wb
     if_def = &IF_A1 : A1 : R :  4587.00 MHz : U ; * PCall off!   0.0   0.0  NA     0 NA
     if_def = &IF_B1 : B1 : L :  4587.00 MHz : U ; * PCall off!   0.0   0.0  NA     0 NA
enddef;
*
def LO@4600MHzDPolNoTone;
```

```
*  mode =  1    stations =Hh
    if_def = &IF_A1 : A1 : R :  4600.00 MHz : U ; * PCall off!   0.0   0.0  NA     0 NA
    if_def = &IF_B1 : B1 : L :  4600.00 MHz : U ; * PCall off!   0.0   0.0  NA     0 NA
enddef;
*--------------------------------------------------------------------------------
$BBC;
*
def 16BBCs;
*  mode =  1    stations =On
   BBC_assign = &BBC01 :  1 : &IF_A1;
   BBC_assign = &BBC09 :  9 : &IF_C1;
   BBC_assign = &BBC02 :  2 : &IF_A1;
   BBC_assign = &BBC10 : 10 : &IF_C1;
   BBC_assign = &BBC03 :  3 : &IF_A1;
   BBC_assign = &BBC11 : 11 : &IF_C1;
   BBC_assign = &BBC04 :  4 : &IF_A1;
   BBC_assign = &BBC12 : 12 : &IF_C1;
enddef;
*
def 16BBCs#02;
*  mode =  1    stations =Wb:Hh
   BBC_assign = &BBC01 :  1 : &IF_A1;
   BBC_assign = &BBC05 :  5 : &IF_B1;
   BBC_assign = &BBC02 :  2 : &IF_A1;
   BBC_assign = &BBC06 :  6 : &IF_B1;
   BBC_assign = &BBC03 :  3 : &IF_A1;
   BBC_assign = &BBC07 :  7 : &IF_B1;
   BBC_assign = &BBC04 :  4 : &IF_A1;
   BBC_assign = &BBC08 :  8 : &IF_B1;
enddef;
*--------------------------------------------------------------------------------
$PHASE_CAL_DETECT;
*
def NoDetect;
*  mode =  1    stations =On:Wb:Hh
   phase_cal_detect = &NoCal;
enddef;
*--------------------------------------------------------------------------------
$TRACKS;
*
def VDIF.16Ch2bit1to1;
*  mode =  1    stations =On:Wb:Hh
*    firmware_type = DBBC_DDC;
*    format = VDIF, and fan-out = 1
*    mode requires  32.00Mb/s/tr; stations using disks
   track_frame_format = VDIF5032;
   fanout_def =   : &CH01 : sign : 1:  1;
   fanout_def =   : &CH01 :  mag : 1:  1;
   fanout_def =   : &CH02 : sign : 1:  2;
   fanout_def =   : &CH02 :  mag : 1:  2;
   fanout_def =   : &CH03 : sign : 1:  3;
   fanout_def =   : &CH03 :  mag : 1:  3;
   fanout_def =   : &CH04 : sign : 1:  4;
   fanout_def =   : &CH04 :  mag : 1:  4;
   fanout_def =   : &CH05 : sign : 1:  5;
   fanout_def =   : &CH05 :  mag : 1:  5;
   fanout_def =   : &CH06 : sign : 1:  6;
   fanout_def =   : &CH06 :  mag : 1:  6;
   fanout_def =   : &CH07 : sign : 1:  7;
   fanout_def =   : &CH07 :  mag : 1:  7;
   fanout_def =   : &CH08 : sign : 1:  8;
   fanout_def =   : &CH08 :  mag : 1:  8;
   fanout_def =   : &CH09 : sign : 1:  9;
   fanout_def =   : &CH09 :  mag : 1:  9;
   fanout_def =   : &CH10 : sign : 1: 10;
   fanout_def =   : &CH10 :  mag : 1: 10;
   fanout_def =   : &CH11 : sign : 1: 11;
   fanout_def =   : &CH11 :  mag : 1: 11;
   fanout_def =   : &CH12 : sign : 1: 12;
```

```
      fanout_def =   : &CH12 :  mag : 1: 12;
      fanout_def =   : &CH13 : sign : 1: 13;
      fanout_def =   : &CH13 :  mag : 1: 13;
      fanout_def =   : &CH14 : sign : 1: 14;
      fanout_def =   : &CH14 :  mag : 1: 14;
      fanout_def =   : &CH15 : sign : 1: 15;
      fanout_def =   : &CH15 :  mag : 1: 15;
      fanout_def =   : &CH16 : sign : 1: 16;
      fanout_def =   : &CH16 :  mag : 1: 16;
enddef;
*------------------------------------------------------------------------------
$BITSTREAMS;
*
def HhBitstreams;
*   Stations = Hh:On:Wb
*   Modes = setup
    stream_def = &CH01 : sign : 16 : 16;
    stream_def = &CH01 :  mag : 17 : 17;
    stream_def = &CH02 : sign : 24 : 24;
    stream_def = &CH02 :  mag : 25 : 25;
    stream_def = &CH03 : sign : 0 : 0;
    stream_def = &CH03 :  mag : 1 : 1;
    stream_def = &CH04 : sign : 8 : 8;
    stream_def = &CH04 :  mag : 9 : 9;
    stream_def = &CH05 : sign : 18 : 18;
    stream_def = &CH05 :  mag : 19 : 19;
    stream_def = &CH06 : sign : 26 : 26;
    stream_def = &CH06 :  mag : 27 : 27;
    stream_def = &CH07 : sign : 2 : 2;
    stream_def = &CH07 :  mag : 3 : 3;
    stream_def = &CH08 : sign : 10 : 10;
    stream_def = &CH08 :  mag : 11 : 11;
    stream_def = &CH09 : sign : 20 : 20;
    stream_def = &CH09 :  mag : 21 : 21;
    stream_def = &CH10 : sign : 28 : 28;
    stream_def = &CH10 :  mag : 29 : 29;
    stream_def = &CH11 : sign : 4 : 4;
    stream_def = &CH11 :  mag : 5 : 5;
    stream_def = &CH12 : sign : 12 : 12;
    stream_def = &CH12 :  mag : 13 : 13;
    stream_def = &CH13 : sign : 22 : 22;
    stream_def = &CH13 :  mag : 23 : 23;
    stream_def = &CH14 : sign : 30 : 30;
    stream_def = &CH14 :  mag : 31 : 31;
    stream_def = &CH15 : sign : 6 : 6;
    stream_def = &CH15 :  mag : 7 : 7;
    stream_def = &CH16 : sign : 14 : 14;
    stream_def = &CH16 :  mag : 15 : 15;
enddef;
*
*------------------------------------------------------------------------------
$THREADS;
*
def HhThreads;
*   Stations = Hh:On:Wb
*   Modes = setup
 format = VDIF : : 1024;
 thread = 0 : 1 : 1 : 1024 : 16 : 2 : : : 8000;
 channel = &CH01 : 0 : 8;
 channel = &CH02 : 0 : 12;
 channel = &CH03 : 0 : 0;
 channel = &CH04 : 0 : 4;
 channel = &CH05 : 0 : 9;
 channel = &CH06 : 0 : 13;
 channel = &CH07 : 0 : 1;
 channel = &CH08 : 0 : 5;
 channel = &CH09 : 0 : 10;
 channel = &CH10 : 0 : 14;
 channel = &CH11 : 0 : 2;
```

```
  channel = &CH12 : 0 : 6;
  channel = &CH13 : 0 : 11;
  channel = &CH14 : 0 : 15;
  channel = &CH15 : 0 : 3;
  channel = &CH16 : 0 : 7;
enddef;
*
*------------------------------------------------------------------------
$HEAD_POS;
def DiskVoid;
* mode =  1    stations =On:Wb:Hh
*     Head positions irrelevant for Disk: empty def
enddef;
*------------------------------------------------------------------------
$PASS_ORDER;
*
def DiskVoid;
* mode =  1    stations =On:Wb:Hh
*     Pass orders irrelevant for Disk: empty def
enddef;
*------------------------------------------------------------------------
$ROLL;
*
def NoRoll;
* mode =  1    stations =On:Wb:Hh
*    barrel-roll set to 'roll_off', so reverse-roll by  0 (1 head)
    roll = off;
enddef;
*------------------------------------------------------------------------
$SCHED;
* schedule section for experiment FR059
* FR059
scan No0001;
    start=2019y119d07h00m00s; mode=setup; source=J0019+2021;
*          :data_good:data_stop:goto_foot: pass:  wrap :driv:tape at
    station=On:    0 sec:  600 sec:   0.000 GB:  :      : 1;
    station=Wb:    0 sec:  600 sec:   0.000 GB:  :      : 1;
    station=Hh:    0 sec:  600 sec:   0.000 GB:  :      : 1;
endscan;
scan No0002;
    start=2019y119d07h10m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
    station=On:    0 sec:  300 sec:  77.292 GB:  :      : 1;
    station=Wb:    0 sec:  300 sec:  77.292 GB:  :      : 1;
    station=Hh:    0 sec:  300 sec:  77.292 GB:  :      : 1;
endscan;
scan No0003;
    start=2019y119d07h16m00s; mode=setup; source=J0019+2021;
    station=On:    0 sec:  600 sec: 115.937 GB:  :      : 1;
    station=Wb:    0 sec:  600 sec: 115.937 GB:  :      : 1;
    station=Hh:    0 sec:  600 sec: 115.937 GB:  :      : 1;
endscan;
scan No0004;
    start=2019y119d07h26m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
    station=On:    0 sec:  300 sec: 193.229 GB:  :      : 1;
    station=Wb:    0 sec:  300 sec: 193.229 GB:  :      : 1;
    station=Hh:    0 sec:  300 sec: 193.229 GB:  :      : 1;
endscan;
scan No0005;
    start=2019y119d07h32m00s; mode=setup; source=J0019+2021;
    station=On:    0 sec:  600 sec: 231.875 GB:  :      : 1;
    station=Wb:    0 sec:  600 sec: 231.875 GB:  :      : 1;
    station=Hh:    0 sec:  600 sec: 231.875 GB:  :      : 1;
endscan;
scan No0006;
    start=2019y119d07h42m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
    station=On:    0 sec:  300 sec: 309.166 GB:  :      : 1;
```

```
     station=Wb:    0 sec:  300 sec:  309.166 GB:  :      : 1;
     station=Hh:    0 sec:  300 sec:  309.166 GB:  :      : 1;
 endscan;
 scan No0007;
     start=2019y119d07h48m00s; mode=setup; source=J0019+2021;
     station=On:    0 sec:  600 sec:  347.812 GB:  :      : 1;
     station=Wb:    0 sec:  600 sec:  347.812 GB:  :      : 1;
     station=Hh:    0 sec:  600 sec:  347.812 GB:  :      : 1;
 endscan;
 scan No0008;
     start=2019y119d07h58m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
     station=On:    0 sec:  300 sec:  425.103 GB:  :      : 1;
     station=Wb:    0 sec:  300 sec:  425.103 GB:  :      : 1;
     station=Hh:    0 sec:  300 sec:  425.103 GB:  :      : 1;
 endscan;
 scan No0009;
     start=2019y119d08h04m00s; mode=setup; source=J0019+2021;
     station=On:    0 sec:  600 sec:  463.749 GB:  :      : 1;
     station=Wb:    0 sec:  600 sec:  463.749 GB:  :      : 1;
     station=Hh:    0 sec:  600 sec:  463.749 GB:  :      : 1;
 endscan;
 scan No0010;
     start=2019y119d08h14m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
     station=On:    0 sec:  300 sec:  541.041 GB:  :      : 1;
     station=Wb:    0 sec:  300 sec:  541.041 GB:  :      : 1;
     station=Hh:    0 sec:  300 sec:  541.041 GB:  :      : 1;
 endscan;
 scan No0011;
     start=2019y119d08h20m00s; mode=setup; source=J0019+2021;
     station=On:    0 sec:  600 sec:  579.686 GB:  :      : 1;
     station=Wb:    0 sec:  600 sec:  579.686 GB:  :      : 1;
     station=Hh:    0 sec:  600 sec:  579.686 GB:  :      : 1;
 endscan;
 scan No0012;
     start=2019y119d08h30m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
     station=On:    0 sec:  300 sec:  656.978 GB:  :      : 1;
     station=Wb:    0 sec:  300 sec:  656.978 GB:  :      : 1;
     station=Hh:    0 sec:  300 sec:  656.978 GB:  :      : 1;
 endscan;
 scan No0013;
     start=2019y119d08h36m00s; mode=setup; source=J0019+2021;
     station=On:    0 sec:  600 sec:  695.624 GB:  :      : 1;
     station=Wb:    0 sec:  600 sec:  695.624 GB:  :      : 1;
     station=Hh:    0 sec:  600 sec:  695.624 GB:  :      : 1;
 endscan;
 scan No0014;
     start=2019y119d08h46m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
 *          :data_good:data_stop:goto_foot: pass:  wrap :driv:tape at
     station=On:    0 sec:  300 sec:  772.915 GB:  :      : 1;
     station=Wb:    0 sec:  300 sec:  772.915 GB:  :      : 1;
     station=Hh:    0 sec:  300 sec:  772.915 GB:  :      : 1;
 endscan;
 scan No0015;
     start=2019y119d08h52m00s; mode=setup; source=J0019+2021;
     station=On:    0 sec:  600 sec:  811.561 GB:  :      : 1;
     station=Wb:    0 sec:  600 sec:  811.561 GB:  :      : 1;
     station=Hh:    0 sec:  600 sec:  811.561 GB:  :      : 1;
 endscan;
 scan No0016;
     start=2019y119d09h02m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
     station=On:    0 sec:  300 sec:  888.852 GB:  :      : 1;
     station=Wb:    0 sec:  300 sec:  888.852 GB:  :      : 1;
     station=Hh:    0 sec:  300 sec:  888.852 GB:  :      : 1;
 endscan;
```

```
scan No0017;
    start=2019y119d09h08m00s; mode=setup; source=J0019+2021;
    station=On:   0 sec:  600 sec:  927.498 GB: :      : 1;
    station=Wb:   0 sec:  600 sec:  927.498 GB: :      : 1;
    station=Hh:   0 sec:  600 sec:  927.498 GB: :      : 1;
endscan;
scan No0018;
    start=2019y119d09h18m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
    station=On:   0 sec:  300 sec:  1004.790 GB: :      : 1;
    station=Wb:   0 sec:  300 sec:  1004.790 GB: :      : 1;
    station=Hh:   0 sec:  300 sec:  1004.790 GB: :      : 1;
endscan;
scan No0019;
    start=2019y119d09h24m00s; mode=setup; source=J0019+2021;
    station=On:   0 sec:  600 sec:  1043.435 GB: :      : 1;
    station=Wb:   0 sec:  600 sec:  1043.435 GB: :      : 1;
    station=Hh:   0 sec:  600 sec:  1043.435 GB: :      : 1;
endscan;
scan No0020;
    start=2019y119d09h34m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
    station=On:   0 sec:  300 sec:  1120.727 GB: :      : 1;
    station=Wb:   0 sec:  300 sec:  1120.727 GB: :      : 1;
    station=Hh:   0 sec:  300 sec:  1120.727 GB: :      : 1;
endscan;
scan No0021;
    start=2019y119d09h40m00s; mode=setup; source=J0019+2021;
    station=On:   0 sec:  600 sec:  1159.373 GB: :      : 1;
    station=Wb:   0 sec:  600 sec:  1159.373 GB: :      : 1;
    station=Hh:   0 sec:  600 sec:  1159.373 GB: :      : 1;
endscan;
scan No0022;
    start=2019y119d09h50m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
    station=On:   0 sec:  300 sec:  1236.664 GB: :      : 1;
    station=Wb:   0 sec:  300 sec:  1236.664 GB: :      : 1;
    station=Hh:   0 sec:  300 sec:  1236.664 GB: :      : 1;
endscan;
scan No0023;
    start=2019y119d09h56m00s; mode=setup; source=J0019+2021;
    station=On:   0 sec:  600 sec:  1275.310 GB: :      : 1;
    station=Wb:   0 sec:  600 sec:  1275.310 GB: :      : 1;
    station=Hh:   0 sec:  600 sec:  1275.310 GB: :      : 1;
endscan;
scan No0024;
    start=2019y119d10h06m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
    station=On:   0 sec:  300 sec:  1352.601 GB: :      : 1;
    station=Wb:   0 sec:  300 sec:  1352.601 GB: :      : 1;
    station=Hh:   0 sec:  300 sec:  1352.601 GB: :      : 1;
endscan;
scan No0025;
    start=2019y119d10h12m00s; mode=setup; source=J0019+2021;
    station=On:   0 sec:  600 sec:  1391.247 GB: :      : 1;
    station=Wb:   0 sec:  600 sec:  1391.247 GB: :      : 1;
    station=Hh:   0 sec:  600 sec:  1391.247 GB: :      : 1;
endscan;
scan No0026;
    start=2019y119d10h22m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
    station=On:   0 sec:  300 sec:  1468.539 GB: :      : 1;
    station=Wb:   0 sec:  300 sec:  1468.539 GB: :      : 1;
    station=Hh:   0 sec:  300 sec:  1468.539 GB: :      : 1;
endscan;
scan No0027;
    start=2019y119d10h28m00s; mode=setup; source=J0019+2021;
*           :data_good:data_stop:goto_foot: pass:  wrap :driv:tape at
    station=On:   0 sec:  600 sec:  1507.184 GB: :      : 1;
```

```
      station=Wb:   0 sec:  600 sec: 1507.184 GB:   :     : 1;
      station=Hh:   0 sec:  600 sec: 1507.184 GB:   :     : 1;
endscan;
scan No0028;
     start=2019y119d10h38m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
      station=On:   0 sec:  300 sec: 1584.476 GB:   :     : 1;
      station=Wb:   0 sec:  300 sec: 1584.476 GB:   :     : 1;
      station=Hh:   0 sec:  300 sec: 1584.476 GB:   :     : 1;
endscan;
scan No0029;
     start=2019y119d10h44m00s; mode=setup; source=J0019+2021;
      station=On:   0 sec:  600 sec: 1623.122 GB:   :     : 1;
      station=Wb:   0 sec:  600 sec: 1623.122 GB:   :     : 1;
      station=Hh:   0 sec:  600 sec: 1623.122 GB:   :     : 1;
endscan;
scan No0030;
     start=2019y119d10h54m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
      station=On:   0 sec:  300 sec: 1700.413 GB:   :     : 1;
      station=Wb:   0 sec:  300 sec: 1700.413 GB:   :     : 1;
      station=Hh:   0 sec:  300 sec: 1700.413 GB:   :     : 1;
endscan;
scan No0031;
     start=2019y119d11h00m00s; mode=setup; source=J0019+2021;
      station=On:   0 sec:  600 sec: 1739.059 GB:   :     : 1;
      station=Wb:   0 sec:  600 sec: 1739.059 GB:   :     : 1;
      station=Hh:   0 sec:  600 sec: 1739.059 GB:   :     : 1;
endscan;
scan No0032;
     start=2019y119d11h10m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
      station=On:   0 sec:  300 sec: 1816.350 GB:   :     : 1;
      station=Wb:   0 sec:  300 sec: 1816.350 GB:   :     : 1;
      station=Hh:   0 sec:  300 sec: 1816.350 GB:   :     : 1;
endscan;
scan No0033;
     start=2019y119d11h16m00s; mode=setup; source=J0019+2021;
      station=On:   0 sec:  600 sec: 1854.996 GB:   :     : 1;
      station=Wb:   0 sec:  600 sec: 1854.996 GB:   :     : 1;
      station=Hh:   0 sec:  600 sec: 1854.996 GB:   :     : 1;
endscan;
scan No0034;
     start=2019y119d11h26m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
      station=On:   0 sec:  300 sec: 1932.288 GB:   :     : 1;
      station=Wb:   0 sec:  300 sec: 1932.288 GB:   :     : 1;
      station=Hh:   0 sec:  300 sec: 1932.288 GB:   :     : 1;
endscan;
scan No0035;
     start=2019y119d11h32m00s; mode=setup; source=J0019+2021;
      station=On:   0 sec:  600 sec: 1970.933 GB:   :     : 1;
      station=Wb:   0 sec:  600 sec: 1970.933 GB:   :     : 1;
      station=Hh:   0 sec:  600 sec: 1970.933 GB:   :     : 1;
endscan;
scan No0036;
     start=2019y119d11h42m30s; mode=setup; source=PHASE_CENTER;
 source=060912A;
      station=On:   0 sec:  300 sec: 2048.225 GB:   :     : 1;
      station=Wb:   0 sec:  300 sec: 2048.225 GB:   :     : 1;
      station=Hh:   0 sec:  300 sec: 2048.225 GB:   :     : 1;
endscan;
scan No0037;
     start=2019y119d11h48m00s; mode=setup; source=J0019+2021;
      station=On:   0 sec:  600 sec: 2086.871 GB:   :     : 1;
      station=Wb:   0 sec:  600 sec: 2086.871 GB:   :     : 1;
      station=Hh:   0 sec:  600 sec: 2086.871 GB:   :     : 1;
endscan;
scan No0038;
```

```
      start=2019y119d11h58m30s; mode=setup; source=PHASE_CENTER;
source=060912A;
      station=On:   0 sec:   90 sec: 2164.162 GB:  :      : 1;
      station=Wb:   0 sec:   90 sec: 2164.162 GB:  :      : 1;
      station=Hh:   0 sec:   90 sec: 2164.162 GB:  :      : 1;
endscan;
*------------------------------------------------------------------------
$TAPELOG_OBS;      * Experiment: FR059
*------------------------------------------------------------------------
*
*      drive#   VSN           start time         end time
  def HH;
   VSN = 1     : Hh-eVLBI : 2019y119d07h00m00s : 2019y119d12h00m00s;
  enddef;
*
  def ON;
   VSN = 1     : On-eVLBI : 2019y119d07h00m00s : 2019y119d12h00m00s;
  enddef;
*
  def WB;
   VSN = 1     : Wb-eVLBI : 2019y119d07h00m00s : 2019y119d12h00m00s;
  enddef;
*------------------------------------------------------------------------
$CLOCK;          * Experiment: FR059
*------------------------------------------------------------------------
*
*              valid from        clock_early   clock_early_epoch        rate
  def HH;
   clock_early = 2019y119d07h00m00s :   3.431 usec : 2019y119d09h30m00s : -8.80e-09 usec/sec;
  enddef;
*
  def ON;
   clock_early = 2019y119d07h00m00s : -20.619 usec : 2019y119d09h30m00s : -4.40e-07 usec/sec;
  enddef;
*
  def WB;
   clock_early = 2019y119d07h00m00s :  19.720 usec : 2019y119d09h30m00s : -9.65e-08 usec/sec;
  enddef;
*------------------------------------------------------------------------
$EOP; * (Includes predicted values)    Experiment: FR059
*------------------------------------------------------------------------
*
  def EOP118;
   TAI-UTC = 37 sec;
   eop_ref_epoch = 2019y118d00h00m00s;
   num_eop_points= 3;
   eop_interval  = 24 hr;
   ut1-utc   = -0.1460995 sec:-0.1468016 sec:-0.1476330 sec;
   x_wobble  =  0.066198 asec: 0.067302 asec: 0.068506 asec;
   y_wobble  =  0.411382 asec: 0.412192 asec: 0.413003 asec;
   delta_psi = -0.104135 asec:-0.103690 asec:-0.103535 asec;
   delta_eps = -0.011503 asec:-0.011427 asec:-0.011343 asec;
  enddef;
*
*------------------------------------------------------------------------
*
*
```

C.   Appendix: TR001 schedule

```
VEX_rev = 1.5;
$GLOBAL;
  ref $EXPER = TR001;
  ref $EOP = EOP118;

$EXPER;
def TR001;
  exper_name = TR001;
  exper_description = TR001;
  exper_nominal_start = 2019y119d10h47m31s;
  exper_nominal_stop = 2019y119d11h47m31s;
  PI_name = "Automated Trigger";
  PI_email = jops@jive.eu;
  target_correlator = JIVE;
enddef;

$MODE;
def setup;
  ref $IF = LO@4100MHzDPolNoTone:On;
  ref $IF = LO@4587MHzDPolNoTone:Wb;
  ref $IF = LO@4600MHzDPolNoTone:Hh;
  ref $BBC = 16BBCs:On;
  ref $BBC = 16BBCs#02:Hh:Wb;
  ref $BITSTREAMS = HhBitstreams:Hh:On:Wb;
  ref $THREADS = HhThreads:Hh:On:Wb;
  ref $FREQ = 4942.49MHz16x16MHz:On;
  ref $FREQ = 4942.49MHz16x16MHz#02:Hh:Wb;
  ref $TRACKS = VDIF.16Ch2bit1to1:Hh:On:Wb;
  ref $PHASE_CAL_DETECT = NoDetect:Hh:On:Wb;
  ref $PROCEDURES = Mode_01;
enddef;

$STATION;
def On;
  ref $ANTENNA = ONSALA85;
  ref $TAPELOG_OBS = ON;
  ref $CLOCK = ON;
  ref $DAS = FILA10G;
  ref $SITE = ONSALA85;
enddef;
def Hh;
  ref $ANTENNA = HART;
  ref $TAPELOG_OBS = HH;
  ref $CLOCK = HH;
  ref $DAS = FILA10G;
  ref $SITE = HART;
enddef;
def Wb;
  ref $ANTENNA = WSTRBORK;
  ref $TAPELOG_OBS = WB;
  ref $CLOCK = WB;
  ref $DAS = FILA10G;
  ref $SITE = WSTRBORK;
enddef;

$SITE;
def HART;
  site_type = fixed;
  site_name = HART;
  site_ID = Hh;
  site_position = 5085442.75548 m : 2668263.91131 m : -2768696.64306 m;
  site_velocity = 0.0000000e+0 cm/yr : 0.0000000e+0 cm/yr : 0.0000000e+0 cm/yr;
enddef;
def ONSALA85;
```

```
    site_type = fixed;
    site_name = ONSALA85;
    site_ID = On;
    site_position = 3370965.80225 m : 711466.27515 m : 5349664.25661 m;
    site_velocity = 0.0000000e+0 cm/yr : 0.0000000e+0 cm/yr : 0.0000000e+0 cm/yr;
enddef;
def WSTRBORK;
    site_type = fixed;
    site_name = WSTRBORK;
    site_ID = Wb;
    site_position = 3828750.39487 m : 442589.59798 m : 5064921.76488 m;
    site_velocity = 0.0000000e+0 cm/yr : 0.0000000e+0 cm/yr : 0.0000000e+0 cm/yr;
enddef;

$ANTENNA;
def HART;
    axis_offset = 6.6944000 m;
    axis_type = ha:dec;
    antenna_motion = ha : 30.000000 deg/min : 20.000000 sec;
    antenna_motion = dec : 30.000000 deg/min : 20.000000 sec;
enddef;
def ONSALA85;
    axis_offset = 2.1500000 m;
    axis_type = ha:dec;
    antenna_motion = ha : 17.600000 deg/min : 5.0000000 sec;
    antenna_motion = dec : 14.700000 deg/min : 5.0000000 sec;
enddef;
def WSTRBORK;
    axis_offset = 4.9500000 m;
    axis_type = ha:dec;
    antenna_motion = ha : 18.000000 deg/min : 10.000000 sec;
    antenna_motion = dec : 18.000000 deg/min : 10.000000 sec;
enddef;

$DAS;
def 2DBBC+NONE<;
    record_transport_type = Mark5B;
    electronics_rack_type = DBBC;
    number_drives = 2;
    tape_motion = adaptive : 0 min : 0 min : 10 sec;
    headstack = 1 :   : 0;
    headstack = 2 :   : 1;
enddef;
def FILA10G;
    record_transport_type = None;
    electronics_rack_type = DBBC;
enddef;

$SOURCE;
def 0019+203;
    source_name = 0019+203;
    ra = 00h19m37.854s;
    dec = 20d21'45.57";
    ref_coord_frame = J2000;
enddef;
def 00312035;
    source_name = 00312035;
    ra = 00h19m37.854s;
    dec = 20d21'45.57";
    ref_coord_frame = J2000;
enddef;
def 060912A;
    source_name = 060912A;
    ra = 00h21m08.143s;
    dec = 20d58'17.41";
    ref_coord_frame = J2000;
enddef;
def GRB_060912A;
    source_name = GRB_060912A;
```

```
    ra = 00h21m08.13s;
    dec = 20d58'18.5";
    ref_coord_frame = J2000;
enddef;
def J0019+2021;
    source_name = J0019+2021;
    ra = 00h19m37.8545000s;
    dec = 20d21'45.644700";
    ref_coord_frame = J2000;
enddef;
def PHASE_CENTER;
    source_name = PHASE_CENTER;
    ra = 00h21m08.6400000s;
    dec = 20d58'15.600000";
    ref_coord_frame = J2000;
enddef;

$FREQ;
def 4942.49MHz16x16MHz;
    sample_rate = 32.000000 Ms/sec;
    chan_def =   : 4942.4900 MHz : L : 16.000000 MHz : &CH01 : &BBC01 : &NoCal;
    chan_def =   : 4942.4900 MHz : L : 16.000000 MHz : &CH02 : &BBC09 : &NoCal;
    chan_def =   : 4942.4900 MHz : U : 16.000000 MHz : &CH03 : &BBC01 : &NoCal;
    chan_def =   : 4942.4900 MHz : U : 16.000000 MHz : &CH04 : &BBC09 : &NoCal;
    chan_def =   : 4974.4900 MHz : L : 16.000000 MHz : &CH05 : &BBC02 : &NoCal;
    chan_def =   : 4974.4900 MHz : L : 16.000000 MHz : &CH06 : &BBC10 : &NoCal;
    chan_def =   : 4974.4900 MHz : U : 16.000000 MHz : &CH07 : &BBC02 : &NoCal;
    chan_def =   : 4974.4900 MHz : U : 16.000000 MHz : &CH08 : &BBC10 : &NoCal;
    chan_def =   : 5006.4900 MHz : L : 16.000000 MHz : &CH09 : &BBC03 : &NoCal;
    chan_def =   : 5006.4900 MHz : L : 16.000000 MHz : &CH10 : &BBC11 : &NoCal;
    chan_def =   : 5006.4900 MHz : U : 16.000000 MHz : &CH11 : &BBC03 : &NoCal;
    chan_def =   : 5006.4900 MHz : U : 16.000000 MHz : &CH12 : &BBC11 : &NoCal;
    chan_def =   : 5038.4900 MHz : L : 16.000000 MHz : &CH13 : &BBC04 : &NoCal;
    chan_def =   : 5038.4900 MHz : L : 16.000000 MHz : &CH14 : &BBC12 : &NoCal;
    chan_def =   : 5038.4900 MHz : U : 16.000000 MHz : &CH15 : &BBC04 : &NoCal;
    chan_def =   : 5038.4900 MHz : U : 16.000000 MHz : &CH16 : &BBC12 : &NoCal;
enddef;
def 4942.49MHz16x16MHz#02;
    sample_rate = 32.000000 Ms/sec;
    chan_def =   : 4942.4900 MHz : L : 16.000000 MHz : &CH01 : &BBC01 : &NoCal;
    chan_def =   : 4942.4900 MHz : L : 16.000000 MHz : &CH02 : &BBC05 : &NoCal;
    chan_def =   : 4942.4900 MHz : U : 16.000000 MHz : &CH03 : &BBC01 : &NoCal;
    chan_def =   : 4942.4900 MHz : U : 16.000000 MHz : &CH04 : &BBC05 : &NoCal;
    chan_def =   : 4974.4900 MHz : L : 16.000000 MHz : &CH05 : &BBC02 : &NoCal;
    chan_def =   : 4974.4900 MHz : L : 16.000000 MHz : &CH06 : &BBC06 : &NoCal;
    chan_def =   : 4974.4900 MHz : U : 16.000000 MHz : &CH07 : &BBC02 : &NoCal;
    chan_def =   : 4974.4900 MHz : U : 16.000000 MHz : &CH08 : &BBC06 : &NoCal;
    chan_def =   : 5006.4900 MHz : L : 16.000000 MHz : &CH09 : &BBC03 : &NoCal;
    chan_def =   : 5006.4900 MHz : L : 16.000000 MHz : &CH10 : &BBC07 : &NoCal;
    chan_def =   : 5006.4900 MHz : U : 16.000000 MHz : &CH11 : &BBC03 : &NoCal;
    chan_def =   : 5006.4900 MHz : U : 16.000000 MHz : &CH12 : &BBC07 : &NoCal;
    chan_def =   : 5038.4900 MHz : L : 16.000000 MHz : &CH13 : &BBC04 : &NoCal;
    chan_def =   : 5038.4900 MHz : L : 16.000000 MHz : &CH14 : &BBC08 : &NoCal;
    chan_def =   : 5038.4900 MHz : U : 16.000000 MHz : &CH15 : &BBC04 : &NoCal;
    chan_def =   : 5038.4900 MHz : U : 16.000000 MHz : &CH16 : &BBC08 : &NoCal;
enddef;

$IF;
def LO@4100MHzDPolNoTone;
    if_def = &IF_A1 : A1 : R : 4100.0000 MHz : U;
    if_def = &IF_C1 : C1 : L : 4100.0000 MHz : U;
enddef;
def LO@4587MHzDPolNoTone;
    if_def = &IF_A1 : A1 : R : 4587.0000 MHz : U;
    if_def = &IF_B1 : B1 : L : 4587.0000 MHz : U;
enddef;
def LO@4600MHzDPolNoTone;
    if_def = &IF_A1 : A1 : R : 4600.0000 MHz : U;
    if_def = &IF_B1 : B1 : L : 4600.0000 MHz : U;
```

```
enddef;

$BBC;
def 16BBCs;
  BBC_assign = &BBC01 : 1 : &IF_A1;
  BBC_assign = &BBC02 : 2 : &IF_A1;
  BBC_assign = &BBC03 : 3 : &IF_A1;
  BBC_assign = &BBC04 : 4 : &IF_A1;
  BBC_assign = &BBC09 : 9 : &IF_C1;
  BBC_assign = &BBC10 : 10 : &IF_C1;
  BBC_assign = &BBC11 : 11 : &IF_C1;
  BBC_assign = &BBC12 : 12 : &IF_C1;
enddef;
def 16BBCs#02;
  BBC_assign = &BBC01 : 1 : &IF_A1;
  BBC_assign = &BBC02 : 2 : &IF_A1;
  BBC_assign = &BBC03 : 3 : &IF_A1;
  BBC_assign = &BBC04 : 4 : &IF_A1;
  BBC_assign = &BBC05 : 5 : &IF_B1;
  BBC_assign = &BBC06 : 6 : &IF_B1;
  BBC_assign = &BBC07 : 7 : &IF_B1;
  BBC_assign = &BBC08 : 8 : &IF_B1;
enddef;

$PHASE_CAL_DETECT;
def NoDetect;
  phase_cal_detect = &NoCal;
enddef;

$TRACKS;
def VDIF.16Ch2bit1to1;
  track_frame_format = VDIF5032;
  fanout_def =   : &CH01 : sign : 1 : 1;
  fanout_def =   : &CH01 : mag : 1 : 1;
  fanout_def =   : &CH02 : sign : 1 : 2;
  fanout_def =   : &CH02 : mag : 1 : 2;
  fanout_def =   : &CH03 : sign : 1 : 3;
  fanout_def =   : &CH03 : mag : 1 : 3;
  fanout_def =   : &CH04 : sign : 1 : 4;
  fanout_def =   : &CH04 : mag : 1 : 4;
  fanout_def =   : &CH05 : sign : 1 : 5;
  fanout_def =   : &CH05 : mag : 1 : 5;
  fanout_def =   : &CH06 : sign : 1 : 6;
  fanout_def =   : &CH06 : mag : 1 : 6;
  fanout_def =   : &CH07 : sign : 1 : 7;
  fanout_def =   : &CH07 : mag : 1 : 7;
  fanout_def =   : &CH08 : sign : 1 : 8;
  fanout_def =   : &CH08 : mag : 1 : 8;
  fanout_def =   : &CH09 : sign : 1 : 9;
  fanout_def =   : &CH09 : mag : 1 : 9;
  fanout_def =   : &CH10 : sign : 1 : 10;
  fanout_def =   : &CH10 : mag : 1 : 10;
  fanout_def =   : &CH11 : sign : 1 : 11;
  fanout_def =   : &CH11 : mag : 1 : 11;
  fanout_def =   : &CH12 : sign : 1 : 12;
  fanout_def =   : &CH12 : mag : 1 : 12;
  fanout_def =   : &CH13 : sign : 1 : 13;
  fanout_def =   : &CH13 : mag : 1 : 13;
  fanout_def =   : &CH14 : sign : 1 : 14;
  fanout_def =   : &CH14 : mag : 1 : 14;
  fanout_def =   : &CH15 : sign : 1 : 15;
  fanout_def =   : &CH15 : mag : 1 : 15;
  fanout_def =   : &CH16 : sign : 1 : 16;
  fanout_def =   : &CH16 : mag : 1 : 16;
enddef;

$TAPELOG_OBS;
def HH;
  VSN = 1 : Hh-eVLBI : 2019y119d10h47m31s : 2019y119d11h47m31s;
```

```
enddef;
def ON;
  VSN = 1 : On-eVLBI : 2019y119d10h47m31s : 2019y119d11h47m31s;
enddef;
def WB;
  VSN = 1 : Wb-eVLBI : 2019y119d10h47m31s : 2019y119d11h47m31s;
enddef;

$BITSTREAMS;
def HhBitstreams;
  stream_def = &CH01 : sign : 16 : 16;
  stream_def = &CH01 : mag : 17 : 17;
  stream_def = &CH02 : sign : 24 : 24;
  stream_def = &CH02 : mag : 25 : 25;
  stream_def = &CH03 : sign : 0 : 0;
  stream_def = &CH03 : mag : 1 : 1;
  stream_def = &CH04 : sign : 8 : 8;
  stream_def = &CH04 : mag : 9 : 9;
  stream_def = &CH05 : sign : 18 : 18;
  stream_def = &CH05 : mag : 19 : 19;
  stream_def = &CH06 : sign : 26 : 26;
  stream_def = &CH06 : mag : 27 : 27;
  stream_def = &CH07 : sign : 2 : 2;
  stream_def = &CH07 : mag : 3 : 3;
  stream_def = &CH08 : sign : 10 : 10;
  stream_def = &CH08 : mag : 11 : 11;
  stream_def = &CH09 : sign : 20 : 20;
  stream_def = &CH09 : mag : 21 : 21;
  stream_def = &CH10 : sign : 28 : 28;
  stream_def = &CH10 : mag : 29 : 29;
  stream_def = &CH11 : sign : 4 : 4;
  stream_def = &CH11 : mag : 5 : 5;
  stream_def = &CH12 : sign : 12 : 12;
  stream_def = &CH12 : mag : 13 : 13;
  stream_def = &CH13 : sign : 22 : 22;
  stream_def = &CH13 : mag : 23 : 23;
  stream_def = &CH14 : sign : 30 : 30;
  stream_def = &CH14 : mag : 31 : 31;
  stream_def = &CH15 : sign : 6 : 6;
  stream_def = &CH15 : mag : 7 : 7;
  stream_def = &CH16 : sign : 14 : 14;
  stream_def = &CH16 : mag : 15 : 15;
enddef;

$THREADS;
def HhThreads;
  format = vdif :   : 1024;
  channel = &CH01 : 0 : 8;
  channel = &CH02 : 0 : 12;
  channel = &CH03 : 0 : 0;
  channel = &CH04 : 0 : 4;
  channel = &CH05 : 0 : 9;
  channel = &CH06 : 0 : 13;
  channel = &CH07 : 0 : 1;
  channel = &CH08 : 0 : 5;
  channel = &CH09 : 0 : 10;
  channel = &CH10 : 0 : 14;
  channel = &CH11 : 0 : 2;
  channel = &CH12 : 0 : 6;
  channel = &CH13 : 0 : 11;
  channel = &CH14 : 0 : 15;
  channel = &CH15 : 0 : 3;
  channel = &CH16 : 0 : 7;
  thread = 0 : 1 : 1 : 1024 : 16 : 2 :   :   : 8000;
enddef;

$SCHED;
scan No0001;
  start = 2019y119d10h47m31s;
```

```
  mode = setup;
   station = Hh : 0 sec : 300 sec : 0.000 GB :   :   : 1;
   station = On : 0 sec : 300 sec : 0.000 GB :   :   : 1;
   station = Wb : 0 sec : 300 sec : 0.000 GB :   :   : 1;
   source = J0019+2021;
  endscan;
  scan No0002;
   start = 2019y119d10h53m01s;
   mode = setup;
   station = Hh : 0 sec : 600 sec : 38.646 GB :   :   : 1;
   station = On : 0 sec : 600 sec : 38.646 GB :   :   : 1;
   station = Wb : 0 sec : 600 sec : 38.646 GB :   :   : 1;
   source = PHASE_CENTER;
   source = 00312035;
   source = 0019+203;
   source = GRB_060912A;
   source = 060912A;
  endscan;
  scan No0003;
   start = 2019y119d11h03m31s;
   mode = setup;
   station = Hh : 0 sec : 300 sec : 115.937 GB :   :   : 1;
   station = On : 0 sec : 300 sec : 115.937 GB :   :   : 1;
   station = Wb : 0 sec : 300 sec : 115.937 GB :   :   : 1;
   source = J0019+2021;
  endscan;
  scan No0004;
   start = 2019y119d11h09m01s;
   mode = setup;
   station = Hh : 0 sec : 600 sec : 154.583 GB :   :   : 1;
   station = On : 0 sec : 600 sec : 154.583 GB :   :   : 1;
   station = Wb : 0 sec : 600 sec : 154.583 GB :   :   : 1;
   source = PHASE_CENTER;
   source = 00312035;
   source = 0019+203;
   source = GRB_060912A;
   source = 060912A;
  endscan;
  scan No0005;
   start = 2019y119d11h19m31s;
   mode = setup;
   station = Hh : 0 sec : 300 sec : 231.875 GB :   :   : 1;
   station = On : 0 sec : 300 sec : 231.875 GB :   :   : 1;
   station = Wb : 0 sec : 300 sec : 231.875 GB :   :   : 1;
   source = J0019+2021;
  endscan;
  scan No0006;
   start = 2019y119d11h25m01s;
   mode = setup;
   station = Hh : 0 sec : 600 sec : 270.520 GB :   :   : 1;
   station = On : 0 sec : 600 sec : 270.520 GB :   :   : 1;
   station = Wb : 0 sec : 600 sec : 270.520 GB :   :   : 1;
   source = PHASE_CENTER;
   source = 00312035;
   source = 0019+203;
   source = GRB_060912A;
   source = 060912A;
  endscan;
  scan No0007;
   start = 2019y119d11h35m31s;
   mode = setup;
   station = Hh : 0 sec : 300 sec : 347.812 GB :   :   : 1;
   station = On : 0 sec : 300 sec : 347.812 GB :   :   : 1;
   station = Wb : 0 sec : 300 sec : 347.812 GB :   :   : 1;
   source = J0019+2021;
  endscan;
  scan No0008;
   start = 2019y119d11h41m01s;
   mode = setup;
```

```
  station = Hh : 0 sec : 390 sec : 386.458 GB :   :  : 1;
  station = On : 0 sec : 390 sec : 386.458 GB :   :  : 1;
  station = Wb : 0 sec : 390 sec : 386.458 GB :   :  : 1;
  source = PHASE_CENTER;
  source = 00312035;
  source = 0019+203;
  source = GRB_060912A;
  source = 060912A;
endscan;

$CLOCK;
def HH;
  clock_early = 2019y119d10h47m31s : 3.4310 usec : 2019y119d11h17m31s : -8.8000000e-9 usec/sec;
enddef;
def ON;
  clock_early = 2019y119d10h47m31s : -20.6220 usec : 2019y119d11h17m31s : -4.4000000e-7 usec/sec;
enddef;
def WB;
  clock_early = 2019y119d10h47m31s : 19.7200 usec : 2019y119d11h17m31s : -9.6500000e-8 usec/sec;
enddef;

$EOP;
def EOP118;
  TAI-UTC = 37 sec;
  eop_ref_epoch = 2019y118d00h00m00s;
  eop_interval = 24 hr;
  num_eop_points = 3;
  num_nut_points = 0;
  delta_psi = -0.104135 asec : -0.103690 asec : -0.103535 asec;
  delta_eps = -0.011503 asec : -0.011427 asec : -0.011343 asec;
  x_wobble = 0.066198 asec : 0.067302 asec : 0.068506 asec;
  y_wobble = 0.411382 asec : 0.412192 asec : 0.413003 asec;
  ut1-utc = -0.1460995 sec : -0.1468016 sec : -0.1476330 sec;
enddef;
```