SPIRE ICC

User Requirements Document
Instrument Simulator

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1 Introduction and Context

This subsection of the SPIRE ICC URD is intended to cover the topics described in the URD Scope Document as follows:

> **Responsibilities stemming from the need for the ICC to interface with the output from various simulations. These simulations may arise from members of the consortium or the actual Instrument Simulator. The simulation outputs will be used by the AOT designers, data-reduction specialists and scientists to optimize their procedures. It may be found useful to provide direct interfaces with a duplicate of the "instrument simulator" within the ICC itself.**

Note: *at the time being (15/7/00), I(MS) do not quite understand the last sentence of the above statements. In fact, as it appears just below, I also think that the second part of the second sentence ("simulations may arise from […] the actual Instrument Simulator") does not belong here. Thus the following requirements may be off the plate…*

Although already quite precise, this description needs further refinement, particularly concerning the terms "Instrument Simulator" which in the text actually describe two different systems.

An instrument simulator will be used to test all commanding modules, in order to verify that the instrument subsystems can indeed be activated and manipulated through telemetry, to verify that housekeeping data analysis procedures actually function, and that downlinked telemetry comply with its format specification. In this simulator, all instrument subsystems are simulated, except the detectors, which usually are replaced by a module sending out a given pattern for test data. This is not the instrument simulator with which this URD is concerned.

The simulator which is described here is complementary in the sense that it does not necessarily includes the details of how observation parameters are translated into instrument commands, but does its best in simulating actual data coming out of the detectors. It is assumed that the responsibility to provide meaningful simulations of various portions of the FIR/Submm sky does not rest in the ICC but either in the SPIRE consortium or in the larger astronomical community. It is also assumed that the responsibility to develop such a simulator actually rests in the ICC

Such a simulator is required for at least three purposes, that in turn define the users:

- Design Astronomical Observation Template and make sure they allow to reach the scientific goals of SPIRE.
- Optimize observing strategies for scientific programs once the AOT are frozen.
- Compare actual observations with simulations to derive constrain photometric calibration, completeness limit, detection limits…

It should be noted that the actual instrument simulator referred to in the last two points is slightly different from that implied by the first point in the sense that, in the first point, the simulator will have much more degrees of freedom than in the second and third ones.

These three different purposes and user results in slightly different requirements and therefore, I have organized this section of the URD into three subsections, although some requirements may be placed in on section quite arbitrarily, and requirements appearing in one section obviously apply to the following ones given that the sections are more or less in a project time sequence. I

have added a fourth section corresponding to the fact that the ICC will quite likely host this instrument simulator facility (at least in the development stage) and therefore this places requirement on the ICC regarding interfaces it has to maintain between users of the simulator and its developper.

Note: Here also I have considered that since the development of this instrument simulator is an ICC task, any requirement that can be written as "the simulator shall have this property" can be rewritten as "the ICC shall ensure that the simulator has this property". In otherwords, I have considered that for ICC subsystems, requirements "cascade" from the top level (the ICC URD) to the bottom level (the actual subsystem URD). To my mind this ensures that any requirement we foresee now actually makes it to the subsystem level.

2 Astronomical Observation Template design

2.1 Portability

Contrary to the time estimator tool, it is not expected that the instrument simulator will be run in many environment other than the ICC's. To allow simple maintenance, the instrument simulator shall be developed in an environment identical to the ICC's.

2.2 Modularity

The ICC shall make sure that the instrument simulator is kept as modular as possible (with one module performing one stage of the simulation) to ensure both simple maintenace and upgrading and the possibility to turn some modules off in case the effect they simulate is not longer needed, or specific experiments requires it.

2.3 Input fields - format

It is assumed that astronomical simulation of the sky seen by SPIRE will consist of images, where integration in the SPIRE band-pass has already occurred, or of spectral cubes, in the case where a spectroscopic observation is to be simulated. The instrument simulator shall be able to ingest both type of data. To simplify exchanges between various sky simulation tools and the instrument simulator, the instrument simulator shall use fits files for inputs.

2.4 Input fields – content

It is assumed that the inputs to the instrument simulator provided by simulations are comprehensive, i.e. they include all sources of FIR/Submm photon, so that the instrument simulator can consider that these images, or data cubes truly represent the sky (i.e. backgrounds and foregrounds are included in the simulated input fields).

2.5 Detector properties

In order to allow a sensible design of AOTs, all detector properties shall be included in the simulator (to the best of the instrument scientists' knowledge). This implies that the development shall be made in close connection with the actual calibration of the instrument, so that no noise sources, or detector characteristics are overlooked.

2.6 Telescope properties

It is likely that the telescope properties (such as pointing accuracies, slewing speed) will have a large impact on AOT design choices. Therefore these telescope properties shall be included in the instrument simulator.

2.7 Non-simulated effects – design stage

A number of effects that could occur in actual operations of the instrument may be too complex to simulate accurately (such as the effect of particle impacts on the detectors). The ICC shall maintain a clear and comprehensive list of the effects not included in the simulator, and of the reasons that led to their non-simulation. These shall be critically inspected on a regular basis.

2.8 Maintenance - parameters

To allow a clear maintenance of the system, and make sure that it always reflect our current knowledge of the instrument (SPIRE/FIRST), all telescope and instrument properties shall be stored in external files (see also the Astronomical Observation Preparation URD), that can have identified versions and be easily upgraded without a major revision of the simulator.

2.9 Outputs – AOT design stage

In principle, the outputs of the instrument simulator should be such that they allow to derive such quantities as signal-to-noise on source, detection limits, observing efficiency. The simplest form of output would be the time-tagged stream of detector readouts. At that stage, given that data-reduction packages will probably be in their infancy, no requirements should be placed on the actual format of these results. However, to allow further analysis, the output format shall be compatible with the environment chosen for SPIRE data reduction

2.10 Outputs – Analysis

Although it is not foreseen that a complete data analysis system will exist at that stage, the ICC shall make sure that the detector outputs produced by the instrument simulator can be transformed in a format that is more meaningful to the users, i.e. object and noise maps or datacubes. This module can be included in the simulator itself but the ability to recover the detector data streams as procuded by the simulator shall be kept.

3 Observing strategy optimization

It should be mentionned here that for that stage, the use of the instrument simulator described here will serve a purpose very close to that of the time estimator tool, and that one could envision to merge the two systems. It is not so clear that this option is the best one. Indeed some modules and algorithms can be common to both systems. However quite a number of potential observers will not go as far as simulating in details the sky for their observations, and do not require the probably heavy computations that a proper simulation would trigger. Merging the two systems would thus probably cause more problems than it would solve: simple-minded user might get scared by the complexity of the system, annoyed by its large outputs, and the versatility of the system resulting from the need to fullfill both sets of requirement may lead to a more difficult development. However, given that the two system are close, a requirement is placed on both to be developed and to evolve in a joint process.

3.1 Commonalities

It is clear that for this purpose, the instrument simulator and the time estimator tool probably will have common needs. Therefore it is the ICC task to make sure that common systems are well identified and not developed twice by different teams.

3.2 Functionalities

At that stage, AOT design will have been frozen, thus the simulator functionalities must implement all the AOTs that have been selected for SPIRE, in all their possibilities. Functionalities extending beyond the selected AOT should be kept available in order to allow simulation of observations performed in non-AOT mode (directly uplinking command sequences, a mode that can be useful for calibration observations).

3.3 Maintenance – system

Optimizing the observing strategy requires that the simulator be up to date. Therefore the instrument and telescope parameters shall be maintained as up-to-date as possible, in order to always describe our current knowledge of the system. These maintenance practices shall be kepts during the whole lifetime of the system. Releases of the system shall have version numbers and be documented so that no-one uses an outdates system unknowingly and the state of the simulator compared to the actual instrument can be assessed efficiently.

4 Comparison with actual observations

4.1 Data reduction system

An obvious requirement for this stage to make sense is that the ICC makes sure that a comprehensive data analysis system is available to users.

4.2 When to upgrade the system

When that stage comes into play, the instrument will be in operation, or the ICC will be in the post-Operation phase. It is foreseen that calibration file and status will be regularly upgraded. Such and upgrading of the instrument calibration files shall trigger a similar upgrading of the instrument simulator.

4.3 Outputs – format

At that stage, the data reduction system will exist and the simulator shall be able to produce outputs that are identical in format to actual data, so that they can directly be ingested by all the data analysis systems (pipelines or procedure) for immediate comparison with actual data. In principle, once the format of the actual instrument output data is known, the simulator should use it.

4.4 Implicit data reduction

At that stage, the aim of the instrument simulator is to provide a template on which to check and compare an actual observation (in order, for instance, to determine detection limits). Therefore the ICC must make sure that the instrument simulator does not perform implicit data reduction before delivering its output, except that occuring on board, or that these steps can be easily reversed so that the user obtains data that can be considered strictly identical to actual data.

5 Host requirements

5.1 Readiness

The freezing of AOT designs will occur quite early in the ICC development. Therefore the instrument simulator shall be developed according to a schedule that will bring it in operation at a time when AOT design has not yet occurred in details.

5.2 Documentation

The ICC shall make sure that documentation describing the functionning of the instrument simulator exists and is comprehensive enough to allow non-developpers to upgrade the system. Indeed it is foreseen that it will be used from before launch, to well after cryogenic fluid exhaustion.

5.3 Interfaces for inputs

It is quite likely that more than one team (either in the consortium or in the broader community) will produce sky simulations. To ease the creation of interfaces between their simulation and the instrument simulator, the ICC shall make public the format in which the instrument simulator expects the sky simulation to be.

5.4 Internal interfaces

It is possible that the team in charge of developing and upgrading the instrument simulator be different from the team involved in ground based characterization of the instrument, or in-flight calibration. Since all information gathered in these two processes has to be reflected in the simulator, the ICC shall ensure that it has provided the necessary interfaces for the information to flow between these different teams.

5.5 Overview

A number of systems are already identified that provide some sort of simulation of the instrument. The ICC shall regularly survey the internal consistency of all these systems, and take appropriate actions when such a consistency is no longer maintain.