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The ATST Virtual Instrument Model

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Abstract. The Advanced Technology Solar Telescope (ATST) is intended to be the premier solar observatory for experimental physics. Unlike its night-time counterparts that operate with relatively fixed instrument sets, ATST's science goals and requirements are best met by a laboratory style instrument configuration, where scientific requirements often mean that instrumentation must be assembled by scientists to meet the unique demands of each experiment.

In order to maximize observing efficiency the ATST software and control systems must be designed to operate smoothly in this environment. To meet the requirement of providing flexibility in a laboratory style operations environment, the control system uses a Virtual Instrument Model. This report introduces this model and briefly outlines its salient characteristics. The aim is to provide some insight into the approach being proposed as part of the overall software and controls design and to provide a foundation for discussions on the advantages and disadvantages of using a virtual instrument model.

1. Introduction

The Advanced Technology Solar Telescope (ATST)[1] is a new 4-meter telescope optimized for solar astronomy. It has a number of novel mechanical features as part of that optimization: an off-axis design, heat stop, integrated high-order AO, and a hybrid dome are several of these features. From a software perspective, none of the above pose any particular problem and for that reason the majority of the ATST software systems follow design models commonly used in modern night-time and radio astronomy systems.

One of the key science requirements does have a significant impact on the system design both in mechanical systems and in software. The ATST is required to provide the flexibility inherent in a laboratory environment[2]. The existing Dunn Solar Telescope (DST)[3] at Sunspot, NM, is specifically mentioned as a model that well illustrates the desired flexibility. On the DST a series of opti-

[1] `http://atst.nso.edu/`

[2] "ATST Science Requirements Document", SPEC-0001, p 58

[3] `http://www.nso.edu/nsosp/dst`

cal benches on a protected rotating platform provide the principal support for observing. Scientists can construct instruments specific to their experimental needs from existing components. While a few instruments are 'facility' and consist of a fixed set of components, even these instruments may be combined with other components using dichroics, beam splitters and slit reflections. The ATST mechanical systems provide a similar flexibility through eight optical benches: on a two level rotating coud platform in the telescope pier.

This approach differs considerably from current night-time observatory design. Because most observing stations on night-time telescopes are exposed and often subject to rotating gravity vectors, instruments developed for nighttime observing are more fixed and considerable effort is spent to ensure that each instrument supports a wide range of science experiments. However, an inherent lack of flexibility results. Often the first task required of an astronomer wishing to perform an experiment it to locate a telescope and instrument combination that is capable of performing the experiment. The flexibility provided by the DST and required of the ATST allows the scientist to construct the instrument to meet the needs of the experiment.

Unfortunately, the DST is almost 40 years old and the software and controls system has evolved over this time in a more or less ad hoc fashion. The ATST challenge for software has been to develop a more formal model that supports this flexibility. This formal model is then fit within a general control system patterned after existing modern telescope control system design. This document outlines the observing model used at ATST and concentrates on a description of the *Virtual Instrument Model*: that portion of the observing model supporting flexible, laboratory style operation.

2. The Experiment

Observers at ATST are interested in performing experiments. A central tenant of the ATST control system model is that the system should be adapted to the requirements of the experiment. A laboratory environment provides flexible support to carry out experiments that are likely not understood or defined at the time the laboratory is designed. Consequently, experiments are a formal concept within the model.

In ATST, an Experiment[4] includes a *Science Program* of *Observations* and a *Virtual Instrument* capable of performing those observations. (The Experiment also ultimately includes Results but that aspect is not relevant to this discussion.) Observations contain sequences of operational steps describing the behavior of the instrument. Each operational step consists of a set of configuration parameters and a simple command describing a state change within the instrument, collectively referred to as a Configuration. This use of science programs is typical of modern observatory operations and matches similar functionality provided at SOLIS, Gemini, VLT, ALMA, and other observatories.

[4]A description of the terminology used for ATST observations may be found in the ATST documentation, "Operational Concepts Definition Document", SPEC-0013

What differentiates the ATST approach from these other observatories is that, instead of adapting experiments to fit within the bounds imposed by instruments consisting of fixed components, the ATST observer can construct a virtual instrument from available components to meet the needs of the particular experiment. This provides a great deal of flexibility in the nature of experiments that can be performed at ATST.

3. The Virtual Instrument

Instruments consist of one or more *Components*. Some components may be purely mechanical with no associated software (e.g., a dichroic). Others may be purely software (a sequencer). Most, however, include both mechanical and software aspects (cameras, scanners, etc.). These last components are called Devices.

In a conventional instrument the set of components that comprise the instrument are fixed and permanently associated with each other. Nevertheless, there is some software that understands these associations. Thus the primary difference between a virtual instrument and a conventional instrument is merely that the associations within a virtual instrument are not fixed but rather managed by software. A subtle difference that is implemented in the ATST virtual instrument model is that telescope components can also be associated as part of a virtual instrument. An experiment that needs to perform drift scanning across the solar disk can include the telescope mount as a component. An experiment performing near-limb observations is likely to include the occulter as a component.

Virtual instruments are composable from a set of available components. Scientists, as part of the design of their experiments, construct the instrument they need for the experiment by assembling the requisite components and associating them with a virtual instrument. Virtual instruments are uniquely identified and the component associations are preserved. This allows virtual instruments to be readily reconstructed for future experiments, if needed. Some virtual instruments are used so often that the physical associations are also maintained. These become the *facility instruments* for ATST. Facility instruments include a visible high resolution spectrograph, a near-IR polarimeter, a broad-band imager, various tunable filters, and others. Virtual instrument identifications are also associated with Experiments.

From a control perspective, once the component associations have been made the control of a virtual instrument is identical to that of a conventional instrument. This simplifies the integration of instrument operation within the otherwise conventional ATST control system.

Components are hierarchical and may be composed from other components. In particular, instruments themselves are components. Composition of instruments is a common feature of operation of the DST and is expected to be a key operational characteristic of ATST as well. With a few additional components several facility instruments may be associated into a new virtual instrument.

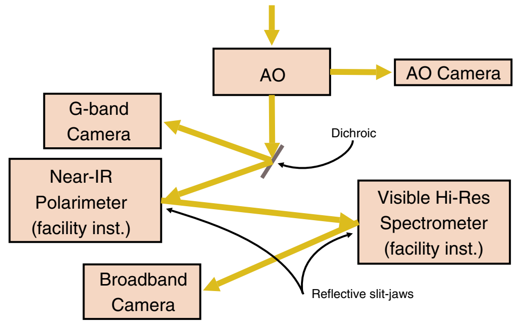

Figure 1. The Balatron Mark IV Virtual Instrument

Figure 1 shows one of several instrument layouts proposed by K.S. Balasubramaniam and G.A. Gary at the May 2003 ATST Boulder Workshop[5].

Some experiments require cooperation between ATST and off-site observatories (including off-planet). A virtual instrument may include special proxy components for coordination with off site facilities.

Elements of a virtual instrument do not need to be under computer control; dichroics, beamsplitters and other static optical components need no active control. However, for bookkeeping purposes these *passive components* are included in the definition of a virtual instrument.

4. Issues

The virtual instrument approach does little to address a fundamental issue associated with laboratory style operations. In conventional systems with fixed instruments great care can be, and is, taken to ensure that components are properly aligned and movements are coordinated. In a laboratory environment where instrument components may be assembled, placed, and replaced by observers it is much more difficult to ensure proper alignment automatically. The result is that instrument setup is often more time consuming than with conventional instrumentation. The availability of multiple optical benches provides ATST with the ability to overlap instrument setup and alignment with active observing, however, reducing the effect of this issue on observing efficiency.

5. Summary

The virtual instrument model is a powerful concept for supporting the flexibility inherent in a laboratory environment. It formalizes the approach already used in such environments enabling integration of the laboratory environment into the conventional modern telescope control system.

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[5] `http://atst.nso.edu/meetings/may03`