ARCSAT Upgrade Path

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1. State of ARCSAT

The Astrophysical Research Consortium Small Aperture Telescope (referred to as ARCSAT) has fallen into a precarious state over the last several years. With minimal funding and engineering support, a modern telescope from 1988, has seen many component failures and is prone to even worse long term failures unless upgrades of critical components can be implemented.

This document will outline the areas of critical failure and generate multiple options to correct and improve the system for many more years usage.

2. Electronics

The current state of the electronics is of concern for the smooth operation of ARCSAT. They have been operational, with minimal down time, since commissioning during the first SDSS survey. Even though these components have been reliable in the past, many points of weakness, and possibly failure, have been identified (see "Preliminary Investigation of ARCSAT Telescope Maintenance Issues", E.Leon). The summation of the electrical problems is the obsolescence and age of components. The following subsections will outline paths of upgrade to mitigate the unforeseen failure of critical components.

Performance also plays a roll in the upgrade options. The performance goals are outline in the "ARCSAT Performance Requirements Document", 2013-07-12. B.Ketzeback put together a table showing some of the critical DFM documented performance specification verse the requirements document goals, see figure 1. Some of these goals, such as tracking accuracy, are not achievable with use of a DFM system solely. To achieve this accuracy hardware external to the telescope, such as a guider, will be necessary. This paper does not go into much discussion on the addition of a guider. This would be a major upgrade project by itself and without first taking care of critical failure points may prove fruitless.

2.1. Option 1: DFM

Option 1 maintains the telescope in its current state. The DOS Telescope Control Software (TCS) and associated electrical and mechanical hardware remain the same. To deal with system failures we would order a spare set of interface cards as well as order a full set of spare components

Fig. 1.—: requirement goals vs DFM specifications

ARCSAT	**Requirements Document (Ver 0.5)**	**DFM**
Blind Pointing Error	~2 arc-min	< 30 arc-sec RMS (Typically, the DFM Engineering TCS and pointing model will achieve 10 to 20 arc-second blind pointing to a 60° zenith distance.)
Tracking accuracy	< 1arc-sec per 20 minutes	+/- 0.5arc-sec in 5 minutes +/- 5.0 arc-sec in 1 hour (or approximately +/- 1.7 arc-sec in 20 minutes)
Variable set, guide and tracking rates	No specification	0 to 4 deg/sec

to repair any individual boards. This option is the easiest as it requires no upgrades to make a semi-robotic telescope. The downside to this option is that some of the electronic components are obsolete and will need to be sole sourced from DFM and it may require more time from our staff to repair and maintain the system.

As part of this upgrade components identified as past their lifetime (such as capacitors) will be replaced.

This option will provide no upgrades in performance and may not (will probably not) meet the set requirements.

Personnel: E.Leon, J.Huehnerhoff

Time to Completion: 0.5 months

Table 1:: DFM Option 1 Cost

Items	Cost
Electrical Components	$1000
Spare Boards	$7000

2.2. Option 2: DFM

Option 2 is a two phase DFM upgrade. The first phase would be to upgrade the TCS with a modern industrial computer running a modern Windows operating system. This will eliminate the failure point of the ancient Gateway 2000 DOS computer and allow us to upgrade to more modern interface drivers. The interface layer is with the ASCOM driver layer, see figure 2. This interface layer will allow the new DFM WinTCS to communicate with a wide/diverse array of softwares, discussed in section 3. No computer circuit boards will be replaced during phase one so we should, at a minimum, stock spare electrical components. The reasoning for not replacing circuit boards is that new versions are currently under development and testing by DFM. The cost for phase one is approximately $13K. This is significantly less than the quote procured in May 2013. The reasoning for the difference is that the May 2013 quote included the addition of Heidenhain absolute encoders to the telescope. Adding these encoders would require significant engineering development by DFM. This cost would have been an additional $35K. After talking with DFM it is not believed necessary to add these encoders.

Phase two of this option would be implemented sometime in 2015 and would be to upgrade the computer cards with new DFM PCI interface and driver cards. The phase two upgrade is not necessary to take advantage of phase one and can be eliminated from the upgrade path if other options are seen as more viable at that time. As part of this upgrade DFM will replace all of our electronic boards with their new motor control system. The new PCI cards will be backwards compatible with our existing telescope hardware so that a swap of the electronics crate should be all that is necessary. DFM will not need to come to site to do the install and it is expected to be a connector to connector swap. Not only should this be a transparent swap, it would be quick. The estimated cost leaked by DFM was that it would be about twice as much as a set of boards. Since a new set of boards is $7K I estimated this upgrade cost to be around $20K. As with any company developing an upgrade they may run into hiccups along the way and so the total time to completion and price are not firm. The finished implementation of this option would be the complete overhaul of every critical electronic system that controls the telescope.

This option receives my recommendation for the best upgrade path option. Reasoning provided in the Recommendations section.

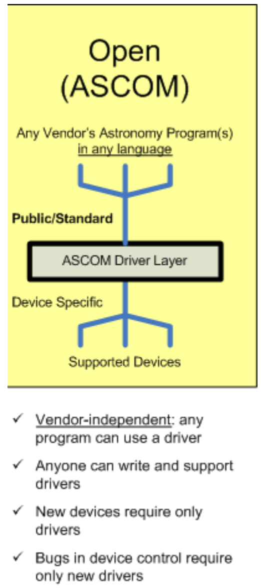
Personnel: E.Leon, B.Ketzeback, J.Huehnerhoff

Time to Completion: 1 month for each phase

Table 2:: DFM Option 2 Cost

Items	Cost
WinTCS	$9700
ASCOM drivers	$3000
Interface Boards (phase two)	$20000 (estimate)

Fig. 2.—: ASCOM interface layer



2.3. Option 3: APO Custom

This option is the most invasive and time consuming as it involves the removal of all DFM electronics and replacement with an ARC personnel engineered replacement.

This option fits in well with the use of R.Owens new TCC program. Some work will have to be done to add equatorial mount path generation to the TCC but this is a minor change to all the work already gone in the the new TCC. Along with a new TCC this option will require new axis controllers, amplifiers, and interface boards. Investigation into the drive system yielded amplifiers that could be purchased through the motor manufacturer. Problems start to surface in the software necessary to merge the telescope amplifiers and the new TCC with an axis controller. A PC104 based axis controller is probably the best option since it is what is used on the 3.5m. Unfortunately a basic version of the 3.5m axis controllers will not work. The equatorial mount telescope with basic servo system is just too different from the 3.5m. A complete new controller system will need to be coded; the time estimated to complete this is 1-3 months. To mate each subsystem together would be custom interface boards. Design and testing of these will also take a substantial amount of time.

A fully customized system such as this will lead to the best performance because we can tune it to our very specific needs and telescope properties. But even this tuning would require a substantial amount of time.

Personnel: E.Leon, R.Owen, C.Sayres, B.Ketzeback, J.Huehnerhoff

- R.Owen - 6 months - TCC, TUI, Controllers

- C.Sayres - 6 months - TCC, TUI, Controllers
- E.Leon - 3 months - Interface boards
- B.Ketzeback & J.Huehnerhoff - 3 months - Testing and Tuning

Time to Completion: 6 months - 12 months

Table 3:: Custom Option Hardware Cost

Items	Cost
Amplifiers	$1000
Controllers	$4000
Interface Boards	$2000
Computer Hardware	$3000
Spares	$5000

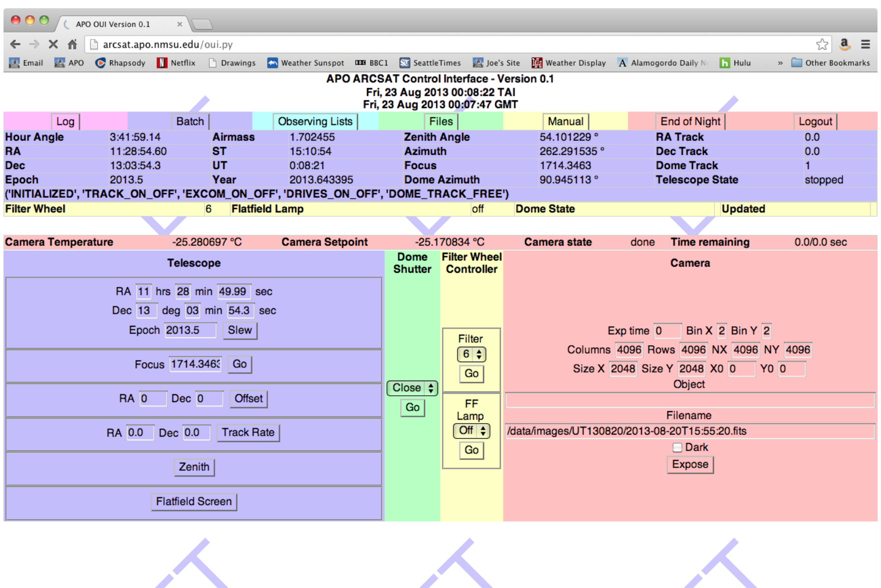
3. Software

3.1. OUI Option

OUI is the current web based python platform used on ARCSAT that has been under development for the last year. It connects with the existing DFM system and allows users to move the telescope and take camera exposures. If we continue with DFM Option 1 of the Electronics upgrade then this is the best option for a user interface but it can also be made to be adapted for any other upgrade option. The difference between the OUI would be the interface layer that connected the user interface to the TCS. The larger the upgrade the more in-depth the changes to OUI, from its current state, would have to be made.

This user interface has had serious development problems over the last year. Since we are still in beta of this software at the time of this paper it is difficult to say this is a non-usable user interface. A demonstration given before September 18th, 2013 will show any major performance and usage issues.

Fig. 3.—: OUI Software



3.2. Off-the-Shelf Option

An off the shelf option recommended by DFM is the ACP Observatory Control Software. This would require the Electronics Upgrade DFM Option 2 due to the communications be through the upgraded ASCOM drivers. This software is intended for amateurs and small universities but contains all the features need to fulfill the requirements document.

A test demo, figure 4, of this software shows the ability to control the telescope in real-time while logging on remotely and the interface does allow multiple users login at the same time. Other features that the software supports that we require are: batch exposures, quick-look at images, supports APOGEE cameras, and can be used on internet enabled devices. A benefit of this software is that it can talk to APOGEE devices through the MaxIm DL software. This means the WinTCS, camera ICC, and User interface will all live on one computer. This software is not as intuitive and clean as TUI but is a good alternative.

An off-the-shelf software such as this will get the telescope operating remotely in a short amount of time. Whether this is the final software or an intermediate option should be discussed.

Table 4:: Off-the-Shelf Software Cost

Items	Cost
DC3 Commercial	$5000
MaxIm DL V5	$665

3.3. TUI Option

The TUI Option can be used on any Electronics Upgrade Option but would be best suited for either Option 2 or Option 3. This would be a rewrite of the current TUI software to strip out the unused portions and interface into the ARCSAT system. The communications would require the addition of a HUB machine as the interface between TUI and telescope. Depending on whether we go with Option 2 or 3 will greatly change the structure of the HUB machine. Option 3 will allow for it to be very similar to the current APO used HUB's. Use with Option 2 will require a much different architecture due to the use of ASCOM drivers. This option will require significant effort by UW personnel: R.Owen and C.Sayres (shown in section 2.3). If we could implement an off-the-shelf option for the short term then it would take pressure off getting the interface completed in the immediate future and minimize telescope down time.

A TUI: ARCSAT version my look something like figure 5.

Fig. 4.—: ACP Software

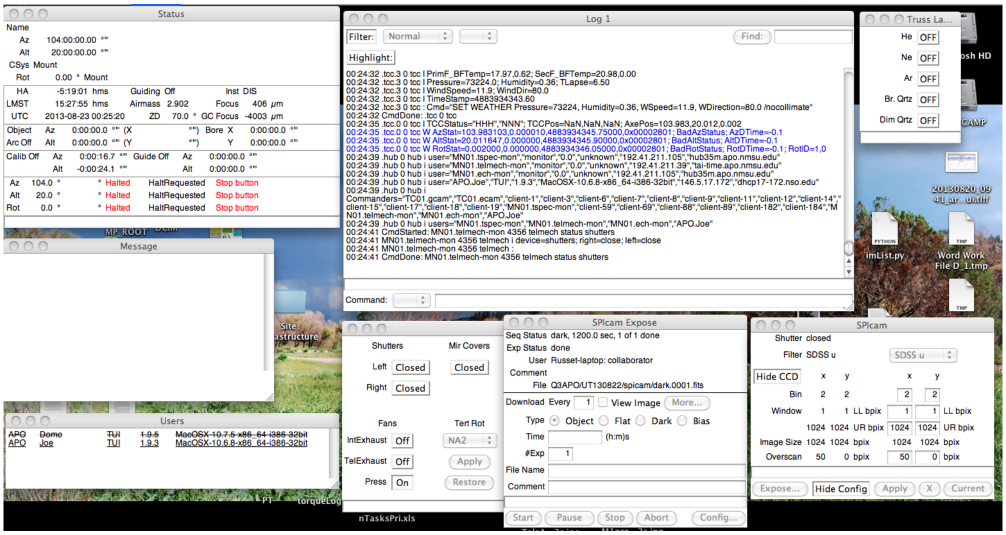
4. Hardware

Regardless of the upgrade path options these upgrades need to be completed: dome controller/sensor, rain sensor, electronics cabinet, telescope cover, and dome roller redesign.

The dome controller will shift all dome control onto the dome itself. Using this method we can just send AC power to the dome and condition it on the dome itself. While changing the method of controlling the dome we can also add appropriate status feedback. This is also where the rain sensor will report conditions. The sensor will be placed near the top of the dome on the exterior and control the emergency open and close protocols in the dome controller. Most of the items have been purchased but with spares and the necessary interface boards the estimated cost is $2000.

An electronics cabinet will be added to clean up the dome and control thermal effects from the computers and associated devices. There is no cost associated with this item.

Fig. 5.—: TUI: ARCSAT Version Software



A telescope cover is necessary to protect the primary. Still in the preliminary design stage, the estimated cost for hardware and control will be approximately $3000.

The drive rollers that hold the dome are not design for radial stresses. Replacing at least 1/3 of these rollers with a system design for axial and radial forces will allow for longer life and less maintenance. This item is still in the preliminary design stage. Estimated Cost is $1500.

5. Cost

Table 5:: Upgrade Cost Comparison

Path	Cost
Option 1	$8000
Option 2	$38365
Option 3	$15000

6. Recommendations

The tradeoffs between each option is the upfront dollar cost vs the man power cost. A custom option does not require much hardware cost but the personnel cost is extremely high and the time to completion very long. An off-the-shelf solution requires significantly more hardware cost but the time to completion is short. The tradeoff is: do we want some else to do the development or do it ourselves. If APO/ARC personnel had spare time, my recommendation would be to build everything ourselves; but, with site commitments it will be very difficult to implement the full, custom option in a timely manner.

Discussion separate from this upgrade paper should be given to guiding. With the average seeing on ARCSAT being around 2" the tracking requirement should be given some thought. If it can be loosened then no guider may be necessary. If a guider is necessary then the development cost could be as much as $15000. This high cost is due to the large change in mechanicals that would be necessary.

Given all this information my recommendation is that we proceed with Option 2 of the electronics upgrade with the off-the-shelf software option to get the telescope up and running quickly. While the telescope is still in operation a ARCSAT TUI and HUB should be coded for implementation sometime over the next year. This could get the telescope remotely operational by October 2014 with subsequent hardware upgrades at the end of 2014 or beginning of 2015.