SOAR Telescope
Echelle Spectrograph

Conceptual Design
Vers. 2 – Nov 2003

Coordinator
Bruno V. Castilho
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1 - Overview

The STELES (SOAR Telescope Echelle Spectrograph) as is a Nasmyth fed, two channels, grating (volume phase holographic (VPH)) cross-dispersed echelle spectrograph, planned for the SOAR Telescope. Both channels will operate in quasi Littrow mode and in white pupil configuration. Using two independent tunable slits, the object and nearby sky spectrum will be recorded from 300-890nm in one exposure with a resolving power of R=50,000. The bench spectrograph will be permanently mounted on the telescope, for stability and easy access (below the Nasmyth platform), and fed by a fore-optics installed in one of the SOAR ISB ports.

B.V. Castilho presented a draft proposal for the STELES spectrograph at the SOAR SAC meeting held at the CTIO in October/2001, and the SAC recommended the preparation of a conceptual design study of the instrument. The first version of the conceptual design was presented to the SOAR board in November/2002, and the instrument was accepted as a SOAR second generation instrument.

The instruments large wavelength coverage with a single configuration, high stability and high resolution, will be a powerful tool, allowing SOAR community to conduct many high impact scientific programs on objects as faint as V=16-17 with high efficiency, and very small impact on SOAR operations.

STELES as currently planned will be built by a team from Brazilian Institutes, Universities and external consultants and contracted companies, under the coordination of Bruno Vaz Castilho from Laboratório Nacional de Astrofísica / MCT. The current list of Institutions and Collaborators can be found in the Personnel Section.

The instrument cost, estimated to be about one million US dollars, will be funded mainly by Brazilian Funding Agencies and is planned to be offered to the SOAR community 2 to 2.5 years after the final design review.

The purpose of this document is to present the conceptual design of the instrument and its main characteristics and capabilities. A management plan that defines the main work packages, a preliminary cost estimate, and the current responsibilities within the project are presented as well.
1.1 – Changes Tracking

In this section we indicate the main differences from this document and the previous version (1 – Oct/2002).

2 - Scientific Drivers: magnitude limit changed (better); search for extra solar planets excluded from the main scientific drivers;

3.1 - General Description: (see optical layout changes);

3.2 - Spectral Format: simulations remade for the new spectrograph parameters;

3.3 - Overall Efficiency: calculations performed;

4.1 – Pre slit: 4.1.1 – pickoff prism: reflection prism changed by a 3 reflection prism;

4.1.3 – Focal Reducer: F/7.5 to F/8.5;

4.1.4 – Dichroics: extended discussion;

4.1.5 – Slits: small description included;

4.2.1 – Collimators: F 7.7 to F/8.5. Spherical instead of parabolic. Secondary collimator placement and size changed;

4.2.2 – Echelle Gratings: red grating changed to a 41.49 l/mm equal to the blue one;

4.2.3 – Crossdispersers: grisms substituted by VPH gratings, discussion added;

4.2.4 – Cameras: Changes in the focal ratios and lenses design; new spectrograph pictures;

4.2.5 – Coatings: more detailed discussion and values;

4.2.6 - Spot Diagrams: recalculated;

5.1 - CCD Detectors: discussion on the possibility of using EEV detectors;

5.2 - CCD Dewar: considerations for using a smaller one;

6 – Mechanical Layout: detailed mechanical drawings developed;

8 - Instrument Control System: preliminary studies of control system included;

9 - Instrument Simulation: raw image simulations and exposure time calculator version 1 implemented and described;

10 - Data reduction Software: goals, tool and methodology described;

13 - Management Plan: totally revised;

Appendix A - Lens Design: Included
1.2 – Chapters co-authors on this document version

2 – Scientifc Drivers: Beatriz Barbuy, Katia Cunha, Gabriel Franco, Gustavo P. Mello, Verne V. Smith, Thais Idiart

3 - Instrument Description and Capabilities: Clemens Gneiding

4 – Optical Layout: Clemens Gneiding, Simone Daflon

6 – Mechanical Layout: designs Leg Engenharia, Vanessa Macahan, Fernando Santoro

8 – Instrument Control System: Leonardo Delefrate, Odilon Giovannini

9 – Instrument Simulation: Jaqueline Vasconcelos, Ricardo Sedyiama

10 – Data Reduction Software: Jaqueline Vasconcelos

13 – Management Plan: Célio Andrade

We wish to thank all the team members that contributed to to produce this document and design concept, and especially to Bernard Delabre (ESO), Robert Tull (Texas Univ.), Luca Pasquini (ESO), as well as Clemens Gneiding (LNA), Steve Heathcote (SOAR) and F. Santoro (LNA/CTIO) for the fruitful discussions.
High-resolution spectroscopy provides a source of large amounts of astrophysical information. A combination of large spectral coverage and high spectral resolution is a powerful tool. A spectrograph with a resolving power of 50,000 and wavelength coverage from 3000 to 8900Å represents such a combination for a variety of studies. The position of STELES in the telescope, bellow the Nasmyth focus of the SOAR telescope, will allow the instrument to be slit-fed, and thus it can be optimized for near-UV work. This would be a powerful addition to Southern Hemisphere astronomy. There is no other 4-m telescope in the Southern Hemisphere with high spectral resolution spectrograph optimized for the near-UV. The high-resolution spectrometer for Gemini South (bHROS) is a fiber-fed instrument (fiber losses in the UV restrict their use to wavelengths redder than about 3500Å).

The STELES design takes advantage of the excellent image quality of the SOAR telescope, and will provide high efficiency, such that stars as faint as V=16-17 will be observable at R=50,000. Estimates show that the spectrum of a star with V=14, having a S/N=100 per pixel, can be obtained in an hour exposure (or S/N=10 at V=18). High-resolution spectroscopy at the magnitude limits described above could be applied to such projects as studies of large numbers of metal-poor stars in the Galaxy, or even to stars in nearby galaxies.

In addition, as it will be coupled to the telescope mounting and fed by the Nasmyth focus, STELES is expected to be very stable. Such a configuration can be used for asteroseismological studies or moderate determinations of radial velocities. In the following section, we list some examples of research projects that would benefit from the facilities offered by the STELES coupled to the SOAR telescope.

*Abundance analyses in the near-UV*: Key projects requiring good efficiency in the near-UV include spectroscopy of the strong electronic OH lines near 3100Å. These particular OH lines are detectable to very low metallicity and are useful in attempts to derive oxygen abundances in the oldest stars in the Galaxy: such O abundances probe the very earliest chemical evolution in the Milky Way. In addition to OH, the element beryllium is only detectable in the near-UV, via Be II lines near 3130Å. Beryllium is produced only through cosmic-ray spallation reactions and is a key probe in understanding cosmic-ray nucleosynthesis over the chemical evolutionary history of the Galaxy.
Chemical Evolution of the Galaxy: The chemical evolution of the Galaxy follows the changes in elemental abundances from their initial values into the present compositions of the disk, bulge and halo. Some examples of specific topics related to this subject are the gradients of metallicity and radial and temporal variations of the star formation rate. Concerning the major components of the Galaxy, the study of the bulge is essential to understand the mechanisms of formation of our Galaxy: the bulge may have been formed in the beginning of our Galaxy, although part of the bulge may have formed significantly later. The study of the oldest halo stars provides crucial lithium abundances which result from primordial Big Bang nucleosynthesis. Young stars in the Galactic disk trace the present distribution of chemical abundances and can be used to determine abundance gradients: these gradients provide constraints to Galactic models of star formation and chemical evolution.

r-Process Enriched Stars: It has been suggested that one likely explanation for the highly r-process enhanced stars that have been identified recently is that they are members of a binary system with a massive companion that exploded as a type II supernova, which would now be a collapsed object such as a black hole. Radial velocity monitoring of the many examples of these stars we hope to find in the near future will be of extreme importance. The same applies to the metal-deficient stars that are moderately enhanced in their r-process elements.

Light Element Abundances: The primordial abundance of light elements and their subsequent Galactic enrichment requires high-quality data to constrain and test their production and evolutionary models. One important problem in this subject is the intrinsic dispersion of Li abundances in dwarf stars of halo globular clusters. Given that globular clusters are among the oldest objects in the Galaxy, their initial Li abundance must be very close to the primordial value. Precise abundance determinations for Li (both 6Li and 7Li) and Be (with only one stable isotope, 9Be) provide essential information relevant to early Galactic cosmic-ray fusion and spallation nucleosynthesis, as well as primordial BBN. Beryllium is an important addition to lithium, but Be is much more difficult to observe. The spectral regions containing the Be II (3130.41Å and 3131.06Å) and Be I lines (3312Å) are crowded and close to the atmospheric cutoff: a near-UV optimized spectrograph, such as STELES, would be an important addition to light element studies.

Cluster Analyses: The determination of accurate abundances in globular cluster stars over a range of magnitudes, covering effective temperatures from 4000 to 6000 K, can address the issue of possible variations in chemical composition existing among stars belonging to the same cluster. This topic is particularly relevant in investigating possible stellar processes, such as diffusion, dredge-up. STELES will be able to investigate stars down to the main-sequence turn-
off (V=17) in several clusters, combining high efficiency with a wide spectral range. Superb image quality, will also allow for spectroscopy in relatively crowded cluster fields.

**Long-Term Velocity Monitoring of Carbon-Enriched Metal-Poor stars:** A large fraction of the stars with [Fe/H] < -2.5 exhibit anomalously strong CH G-bands (and often C2 and CN features) indicative of very high carbon abundance, despite the stars overall low metallicity. It seems quite unlikely that all of the stars involved are members of close binaries that have undergone mass transfer of carbon-enriched material from their companions. Hence, sorting out which of the stars are radial velocity variables and which are not is an important program. Since the periods of known mass-transfer binaries can reach up to 7-8 years (or more, in some cases), gathering data for their study is a challenge with most telescopes. Correlations between measured abundances of (e.g., s-process) elements and orbital properties would provide valuable clues for understanding the range of phenomena and the nature of the progenitors in these systems.

**Asteroseismology of Stars:** Certain structural properties of stellar interiors can be probed by the study of the weak non-radial pulsations in solar-like stars, which cause small radial velocity variations. The simultaneous measurement of many spectral lines leads to the detection of small radial velocity variations.

These are only a few ideas for projects for high-resolution spectroscopy, but many more of high scientific caliber are certainly possible (isotopic ratios; carbon abundance in planetary nebulae; heavy metals abundances in low [Fe/H] stars; stellar rotation, line variability studies, emission lines of novae, SN, H II regions, planetary nebulae, AGN; analysis of absorption spectra of high redshift QSO's; kinematics in galactic nuclei and star clusters, etc). In summary, a high-resolution spectroscopic capability for SOAR will be an important addition to its scientific potential.
3 - Instrument Description and Capabilities

3.1 - General Description

- Two channel, VPH grating crossdispersed echelle spectrograph
- White pupil configuration
- Bench mounted
- Nasmyth focus, slit fed
- Resolving power - 50.000 (3 - 2.5 pixel resolution) with a 0.8" slit. Higher resolution can be achieved with narrower slits.
- Wavelength range - 3000 - 8900Å (blue arm 3000-5500Å, red arm 5300-8900Å)
- CCDs - two 2x4k chips are foreseen, both with 15μm pixels, one blue optimized and the other red optimized.
- Fixed configuration: the bench-mounted sub-assemblies of the spectrograph contain few remotely controlled moving components. This ensures reproducibility and stability of the instrument and a less expensive operation and maintenance.
- On-line data reduction software will be available for fast analysis of the acquired data.

Table 3.1 - STELES main parameters

<table>
<thead>
<tr>
<th></th>
<th>STELES</th>
<th>Blue</th>
<th>Red</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength range in one exposure</td>
<td>3000-8900Å</td>
<td>3000-5500Å</td>
<td>5300-8900Å</td>
</tr>
<tr>
<td>Resolving Power</td>
<td>50k</td>
<td>max. (80 k)</td>
<td>max. (70 k)</td>
</tr>
<tr>
<td>Slit Entrance Aperture (arcsec)</td>
<td>0.8&quot;</td>
<td>min. (~0.5&quot;) - 2pix</td>
<td>min. (~0.6&quot;) - 2pix</td>
</tr>
<tr>
<td>Fore Optics Input/Output</td>
<td>F / 16 - F / 8.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spectrograph Beam Size</td>
<td>100 mm (50mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collimators</td>
<td>F / 8.5</td>
<td>F / 8.5</td>
<td></td>
</tr>
<tr>
<td>Echelles</td>
<td>R4</td>
<td>41.67 gr/mm</td>
<td>41.67 gr/mm</td>
</tr>
<tr>
<td>Crossdisperser VPH grating</td>
<td>1200 gr/mm</td>
<td>600gr/mm</td>
<td></td>
</tr>
<tr>
<td>Dioptric Cameras</td>
<td>F / 3.0</td>
<td>F / 2.5</td>
<td></td>
</tr>
</tbody>
</table>
3.2 - Spectral Format

The spectral format was calculated using the ZEMAX (Optical Design Code) for reference orders and wavelengths and for all orders using a code provided by Robert Tull. Tull’s code values differs by a few (2-3) Angstroms in the dispersion direction and around 1-2 arcsec in the spatial direction from the ZEMAX results. This is possibly because his code was designed for reflection gratings and not for VPH gratings, but the values could give a good idea of the overall spectral format of STELES. The shifted values of uniformity of order spacing, and the spectral ranges are expected to be accurate to about 2%.

The blue channel spectrum format fits a 2x4k CCD (30.7mm wide, 61.4 mm high), with 72 orders. The red channel spectrum format fits a 4x2k CCD (61.4 mm x 30.7 mm) with 38 orders. The order separations are expected to be in the range of 6 arcsec to 23 arcsec in the blue channel and 6 arcsec to 20 arcsec in the red channel, allowing reasonable sky subtraction for a 1 arcsec seeing spot. The ZEMAX spectral formats are presented in Figures 3.1 and 3.2 and the calculated values are presented in Tables A.1 and A.2 (Appendix A).

Figure 3.1 – Envelope of the STELES spectral format over the blue CCD.
Figure 3.2 – Envelope of the STELES spectral format over the red CCD.

A data simulation was performed using IRAF’s noao.artdata.mkechelle package based on the spectrograph parameters and values found with the calculations above. Again some differences were found between the IRAF and ZEMAX simulations probably because the IRAF task was also designed for reflection gratings and not for VPH gratings, but the small differences do not prevent the use of the images for the data reduction software simulations. See Section 9.1 for description and figures.

3.3 - Overall Efficiency

The efficiencies of the spectrograph subsystems and the overall efficiency was calculated using ZEMAX code and theoretical glasses and coatings values. Since the CCD detector are not fully defined for STELES we used two possible CCD choices in the calculations: the 4x2K EEVs and the MIT/LL, ordered by SOAR for the first generation instruments.

In the figures bellow we show the calculated efficiencies for some STELES subsystems and the overall spectrograph efficiency as a function of wavelength. The description of glasses and coatings can be found in Section 4, the one of CCDs in Section 5, and the other components of the calculations are described in Section 9.2. The results are very promising and even accounting a considerable difference (for less unfortunately!) from the theoretical and post commissioning measured results, we still foresee a very efficient spectrograph.
Figure 3.3 – STELES pre slit optics (including dichroic A), and channels efficiency.
Figure 3.4 – STELES + telescope (64%) and ADC (96%) calculated efficiency, for both CCD’s.

In Figure 3.5 we show the calculated the S/N ratio as a function of the visible magnitude of the object and for three different integration times. These values have been derived for $l = 600\text{nm}$ assuming the transmission values discussed in Section 9.2, new moon, a 0.8” seeing, a 0.8” slit, a binning of (1,1), dichroic A, air mass = 1.0, for a blackbody source of 5700K and the detector EEV2.

Under these conditions the spectrum of a star with $m_v = 10$ can be taken in 1 minute with S/N of about 100 per spectral bin, a $m_v = 14$ can reach S/N = 100 in approximately one hour and a S/N = 10 can be reached in approximately the same time for a $m_v = 19$. These numbers are obtained from the best theoretical spectrograph conditions.

Figure 3.5 – Signal-to-Noise ratio per spectral element at 600 nm at different exposure times.
The STELES optical design was done by Bernard Delabre (ESO), using concepts developed for the FEROS and UVES spectrographs. The preliminary design suffered some modifications as a result of the discussions with the project team and the suggestions of the project consultant Robert Tull (Texas Univ.) (See A.2). The present design is an evolution of that one and has major optical modifications, however without altering the spectrograph output characteristics.

As described in Sec. 3, the spectrograph is a two channels, bench mounted, VPH grating crossdispersed, R4 echelle. For both channels the configuration is a quasi Littrow white pupil spectrograph. The optics were calculated for a resolving power of 50,000 (3 - 2.5 pixel resolution) with a 0.8" slit and a wavelength range of 3000 - 8900Å (blue arm: 3000-5500Å, red arm: 5300-8900Å). The field of view of the spectrograph is 30 arcsec but it is limited by the slits decker to prevent order overlapping in the blue part of the CCDs.

The scientific requirement of reaching 3000Å with acceptable efficiency led to the choice of a two channel design, so each channel optics, coatings and CCDs can be optimized. Two 2k x 4k CCDs can accommodate all the wavelength range (3000-8900Å) with R=50,000 with a good spectral sampling (3 pixels); and reach slightly higher resolution with narrower slits. The white pupil layout and refractive catadioptic cameras, as well as the choice of VPH gratings as crossdispersers are intended to improve the instrument efficiency.

Since we intend to observe objects close to the limiting magnitudes, the sky contribution is not negligible and sky subtraction capability is required. The order separation was specified in a way that good sky subtraction (seeing x 10) could be done for a median seeing of 0.8". Moreover being installed in a multi-instrument telescope optimized for high spatial resolution, we can foresee that a significant fraction of the observations with STELES will be done in gray or bright time.

Another constrain driven by the UV choice is that the instrument have to be fed through the Nasmyth focus without the use of optical fibers. Considering that STELES is proposed to be permanently installed on the telescope fork, the instrument would not compete with other Nasmyth instruments and still have stability to be used for moderate precision radial velocity studies.

The lenses design and optical data are show in Appendix C.
4.1 - Fore-optics

The fore-optics system transfers the light from the ISB port to the spectrograph arms through a distance of about 3.2m. The native SOAR F/16 focal ratio is changed to F/8.5 and a field derotator is included in the optical train. Enough clear space is left to insert further optical components into the near collimated beam, close to the derotator, such as filters, ADC etc. Bellow we describe the main components. In Figure 4.3 a schematic view of the fore-optics and its components is shown.

4.1.1 - Pick-off Prism

The first STELES pre slit component is a silica 3 internal reflections prism (30 arcsec field) that deflects the beam 90° allowing the light to reach the focal reducer and spectrograph. As is the case for all the fore-optics components, it must have a very broadband coating to be efficient in the entire wavelength range required.

This solution arises because the need for a broad band very efficient coating prevents the use of a flat mirror. A total reflection prism should be used in a 94° to maintain its total reflection characteristic and this will lead to mechanical risks since all the spectrograph should be mounted following this angle. So we decided for a bigger but equally efficient 3 internal reflections prism. In figure 4.1 the light path through the prism is show. A convergent doublet is cemented to the prism exit to create a focus point close to the transfer lens.

This is the only optical component of STELES pre slit mounted outside the fixed bench. The light goes down to the bench through a baffle tube mounted on the SOAR ISB (see Section 6).
4.1.2 - Transfer Optics

The transfer optics consists of two doublets of Silica / CaF$_2$. The first is cemented to the pick off prism and the second located between the pick off prism and the field derotator, 1419mm from the first. It transfers the beam across the long distance down to the focal reducer, derotator and eventually the spectrograph slit. The lenses design are show in Appendix C. In figure 4.3 we show a fore-optics schematic view with the actual distances.

4.1.3 - Field Derotator and Focal Reducer

This system is an Abbe-Koenig derotator prism of fused silica. It is fed by the F/16 beam from the transfer lens, and after the 3 internal reflections the light passes through a cemented Silica/CaF$_2$ system that slows the beam. After the dichroic mirror (that splits the beam at 5500Å or 5000Å) two doublets re-image the Nasmyth focal plane on the slits at F/8.5. This allows a very compact spectrograph, with a first collimator focal length of 850mm.

4.1.4 - Dichroics

Two dichroic filters are planned for STELES, providing the split of the incoming light at an angle of incidence of 45° and random polarization. The dichroics reflects an average of 95%
or more in the spectral range 3000-5300Å, and transmits more than 90% in 5700-8900Å. Its transition region is centered at 5500Å and has a bandwidth at 50% transmission of approximately 500Å (see Figure 4.4). It has been designed for a fused silica substrate, with a preliminary cost estimate of ~US$2500.00, quoted by Barr Associates. The spectral characteristics of this dichroic are shown in the figure below. A second dichroic is to be designed with a transition region, set according to science requirements, at 5000Å.

In table 4.1 We show some important astronomical features frequently used in the studies of hot stars, cold stars and quasars that lead the choices on the dichroics transition region.

4.1.5 - Slits

The slits mechanism is described in Section 6. Optically they limit the 30 arcsec beam to 8 arcsec high and are designed to work on the range of 2.5 to 0.5 arcsec (limit for a 2 pixels sampling) widths. Higher slits are possible, but there will be sky overlapping in the blue.

4.2 - Spectrograph

The choice of the R4 echelles allows smaller beam size and camera focal lengths, for the same resolution and throughput efficiency. The use of 100mm beam size and F/8.5 collimators provide a very compact design was achieved, allowing the instrument to be mounted on the telescope fork bellow the Nasmyth platform and reducing significantly the material and fabrication costs of the optics. Bellow we describe the spectrograph components. In Figure 4.5 we show the optical diagram of both STELES arms. The rays shown at the camera focal plane represent the central wavelengths in five spectral orders spanning the spectral range for each channel (see Tables in Appendix A).
Figure 4.2 - Derotator prism and collimator lens

Figure 4.3 - STELES fore-optics schematic view (not in scale).
Figure 4.4 - Dichroic efficiency curves calculated for STELES by Barr Associates. Blue reflected and Red transmitted.

Table 4.1 - Some important astronomical features frequently used in the studies of hot stars, cold stars and quasars that lead the choices on the dichroics transition region.

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Figure 4.5 - Zemax layout of both STELES arms.
4.2.1 - Collimators

STELES main collimators are two 850 mm focal length F/8.5 spherical mirrors symmetrically mounted for each channel. In the current STELES design the transfer collimators are placed half way in comparison with the main ones so that the beam diameter is resized 50mm. This change, driven by the choice of VPH gratings as crossdispersers, allow the use of spherical mirrors instead of parabolic ones and shortened the spectrograph length.

Both M2 collimator mirrors are smaller than the M1 ones (M1 diameter = 330mm, M2 = 257mm), even accommodating the larger offset of the beam due to the reversed grating angle $\gamma$. The two spherical mirrors M1 and M2 can be produced easily than the previous design parabolic ones, and could be cut from smaller parent mirrors. The M2 mirrors are smaller and will havr a size of 234 x 105 mm.

4.2.2 - Echelle Gratings

A resolving power of R~50,000 may be achieved with a slit of width $\phi=0.86$ (blue arm) -0.95 (red arm) arc sec and a beam aperture of 100 mm with R4 echelle gratings (blaze angle = 76°). A R4 echelle grating with 41.49 grooves/mm and dimensions of 112×408 mm was chosen for both channels. The dispersion over the 72 orders of the blue channel varies from 1.25 to 2.28 Å/mm and the red channel spectral format comprises 38 orders, with dispersions of 2.66 to 4.31 Å/mm. In both the blue and the red channel, the gratings are used in quasi Littrow mode: the beam is reflected with an angle of 1.0° in the direction perpendicular to the dispersion. The gratings suggested for STELES are from the Spectra Physics (former Richardson Grating Lab.) 2003 diffraction grating catalogue.

4.2.3 - Crossdispersers

At the crossdispersers we have the biggest change from the previous STELES design, which lead to improvements in the spectrograph size, cost and efficiency.

The crossdispersers separate the spectral orders of the echelle operating in very high orders of dispersion. The first crossdispersers chosen for STELES were grisms, which combine the properties of transmission gratings with that of prisms. With this configuration, the required order separation is mostly provided by the grating so that the prism may be smaller than if a
prism was used alone. A Silica grism with 600 grooves/mm and an apex angle of 23.3° was chosen for the blue channel, providing an order separation of 9.0"-21.9". For the red channel a BK7 grism, with 300 grooves/mm and an apex angle = 24.1° was chosen, providing an order separation of 8.2"-19.4". But this choice present two problems during the optical revision: i) the efficiency in the blue is bellow the expected, and ii) the deviation angle required for the dewar placement is not achieved with the chosen grisms.

The possible choices to replace the grisms are prisms and reflection gratings, but both presented disadvantages to the project.

Under certain circumstances, the prism is the best choice, because its transmission is very high over the full spectral range, not presenting blaze effects, and it has only one spectral order. But the necessary dispersion for the blue channel using fused silica prisms (UV transmission) is only reached with 4 prisms in a tandem mounting! So this options is discarded in principle.

The other choice is the reflection grating option already analyzed in the Options report by R. Tull (Appendix B). This choice has no major problems apart from increasing the spectrograph width, consequently making difficult its placement on SOAR. To avoid that a flat folding mirror can be inserted to fold the beam but this option will decrease the efficiency in a few percents and was leave as a possible option.

**Volume Phase Holographic gratings**

Based on this results we choose to investigate a third and more improbable solution that is to use volume phase holographic as crossdispersers. A first look at this option shows two problems: i) the fast decreasing efficiency on the VPH for broad wavelength ranges and ii) the difficult of producing good VPH gratings at the low frequency of lines / mm required by our design (600 l/mm blue, and 300 l/mm red). The first problem have been solved by Wasatch Photonics, which is using and new technique that maintain the efficiency over a broader band. Consulting them we found out that the first limitation still persist. The lowest groove density suggested by them are around 1200 and 600 l/mm for blue and red gratings.

If we use this gratings without further modifications in the spectrograph design we will double our cross dispersion and this will require 2 detectors on each channel to maintain the spectral resolution and coverage. The impact of this solution over the project budget drive us to find out an alternative solution. In discussions with B. Delabre and H. Dekker (ESO) a proposal resulted: decrease the beam diameter by the same amount on the crossdisperser but not on the
echelle. This could be done if the second collimator is placed half way in respect to the first one. Delabre’s design had show that this option is feasible and that a good image quality can be achieved even with spherical mirrors. And as a secondary effect the crossdisperser and camera lens diameter are cut by half.

The chosen gratings for STELES are a 1200 l/mm blazed at 400nm for the blue channel and a 600 l/mm blazed at 600nm for the red channel. To produce an efficient grating that can operate at 300nm Wasatch will use fused silica as substrate and a different UV cement to assemble the protective glass layer. To evaluate this modifications in their production processes they will perform, in the next months, prototyping tests and measure the gratings performances. The proposed cement to substitute the usual Norland NOA-63 is the Epo-Tek 301-2FL that has an enhanced transmission bellow 350nm. The transmission of both cements are show in figure 4.6.
In figures 4.7a and b we show the theoretical efficiencies for the proposed VPHs calculated by Wasatch Photonics, and in figure 4.8 a comparison with reflection and transmission gratings (grisms) efficiencies.
Figure 4.7a – Efficiency curves of the proposed red VPHs calculated by Wasatch Photonics (taken from a standard grating, but it will be optimized to match our requirements).

Figure 4.7b – Efficiency curves of the proposed blu VPHs calculated by Wasatch Photonics.
4.2.4 - Cameras

The cameras have focal ratios F/3.0 (blue) and F/2.5 (red) instead of the F/3.5 and F/3 of the previous ones. This changes were implemented to fit the desired orders on the CCDs.

Both STELES cameras are dioptric systems. With an calculated transmission of about 85%, they have no vignetting or central obstruction. But in the new design the focal plane is not located far enough from the last surface so that a standard dewar window can be used, i.e, the last camera lens will be the detector window and the dewar can not be shared with other instruments. In this case we consider the idea of using a smaller dewar than the one designed by CTIO for the SOAR imager, in order to best fit them in the optical bench (see Section 5).

The cameras will be mounted on linear stage tables that allow the front part of the cameras to be moved relatively to the dewar window to provide focussing. The last lens is a cylindrical one to corrected the collimator aberrations. The red camera uses S-FPL53 and PBH1 and CaF2 glasses, while the blue one, due to the UV requirement, are made of Silica and CaF2.

In Figure 4.9 and 4.10 the optical layout of the cameras are shown. In Figures 4.11 to 4.15 we show 3D renderings of the spectrograph optical layout.
Fig. 4.9 - Blue camera optical layout.

Fig. 4.10 - Red camera optical layout.

Fig. 4.11 - Cameras 3D rendering.
Fig. 4.12 - Spectrograph 3D rendering. Front view

Fig. 4.13 - Spectrograph 3D rendering. Isometric view, top
Fig. 4.14 - Spectrograph 3D rendering. Zoom on the blue arm components.

Fig. 4.15 - Spectrograph 3D rendering. Side view.
4.2.5 - Coatings

The components of the fore-optics, common to both arms (from ISB to dichroic), have to be coated with efficient coatings in the entire spectral range (3000 to 9000 Å), while the blue and red arm lenses can be coated with specific ones. For all reflecting surfaces (2 flat folding and 2 collimator mirrors) we are investigating high-reflectivity coatings in the respective spectral ranges. Below we describe the intended coatings for the STELES subsystems.

- **Pre slit Optics**: The pre slit optics consists of a total reflection prism, a transfer doublet, the field derrotator, the dichroic and a doublet that focuses the light on the slit. The eight glass surfaces will be coated with a broad band multi layer coating as Unaxis (former Balzers) Supertriolin that can be modified with reasonable losses (we estimated a 1% loss over the published value, which give us a mean value of 98.5% transmittance for the pre slit glasses) to reach the 300nm region (see Fig. 4.16). The dichroic efficiency is shown below. The total pre slit efficiency has a mean value of 84% calculated with Zemax.

- **Dichroics**: Two dichroics are foreseen for STELES differing only in the cutting wavelength (500 and 550nm) to permit the observer to choose the spectral region to be on the edge. The transmission and reflection efficiencies were calculated by Barr Associates and are shown in figure 4.4.

![Figure 4.16 – Unaxis Supertriolin and Iralin coatings transmittances.](image)

- **45° mirror and Collimators**: Due to the four reflections in each channel the mirrors should be coated with a high-reflectivity coating for the desired spectral ranges (300-550nm in the blue and 530-900 nm in the red). For the red mirrors (2 collimators and folding mirror) the Unaxis Silflex VIS single-layer coating could be used. For the blue ones a modified version of Silflex or a SiO based coating should be designed. In any case efficiencies of the order of 98.5% could be achieved (see Silflex curve below – Fig. 4.17).
4.2.6 - Spot Diagrams

Blue channel:

Figure 4.17 – Unaxis Silflex transmittance

- **Cameras and corrector lenses**: Since the lenses on both channels need coatings designed for narrower bands in comparison with the pre slit optics we expect transmittance of the order of 99%. For the blue channel we can use a slight modified version of Unaxis Iralin (Fig. 4.16) and for the red channel the standard Unaxis Supertriolin.
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5 - CCD Detectors

5.1 - CCD Detectors

The STELES conceptual design was developed foreseeing the use of two 2k x 4k (15\textmu m pixel) CCD detectors. Depending on the yield of the SOAR consortium in the 4\textsuperscript{th} phase of MIT/LL CCD program, we can use one red and one blue optimized Lincoln Labs detectors; but at this moment this possibility is not very likely. Otherwise the STELES project will have to procure and acquire its own detectors. A third, but not likely possibility also, is that in case of failure or delay of the two first options that we can consider moving the dewars+CCD's from other SOAR instruments for STELES runs temporarily. But this option is also quite unlikely now with the new design of the cameras where the CCD window is not a plan window but the last camera lens. So we have to consider seriously the option of acquiring a detector different from the initial specified ones.

A realistic choice are the EEV2 2Kx4K, 13.5\textmu m pixel devices. These chips are used in many instruments at ESO, AAO and other observatories including SOAR, and have been extensively tested. The change for a EEV detectors on STELES will have impact on the camera/crossdisperser design, UV / IR quantum efficiency and possibly fringing.

The camera and crossdispersers should be adapted to fit spectra on the 13.5\textmu m pixels CCDs instead of the calculated 15mm ones. A small change in the VPH grating grooves density could handle the change in the crossdispersion, but the impact on the cameras has to be analyzed in more detail. The total linear difference between the two chips reaches \textasciitilde 6mm in the 4096 direction.

Tests at ESO (UVES/VLT) and RGO shows that “fringing with these device can be much worse than seen in the MITLL large format CCDs, and even worse than that seen in the TEK CCD. Observations with the RGO spectrograph indicate spectroscopic fringing at a level of \textasciitilde 0.5\% pp at 6000A, 0.5\% p-p at 6500A, 4\% p-p at 7000A, 22\% at 8000A , 58\% p-p at 9000A and 60\% at 10000A. This compares with 3\% p-p at 8500A for the MITLL3, and 6.5\% p-p for the MITLL2a” (EEV2 CCD42-80-5-904 Test, 2001, Chris Tinney, AAO). In Figures 5.1 we show the fringing (images and cut) at the UVES red CCD mosaic, which is made of a EEV chip of the same type (EEV CCD-44) and the MIT/LL CCID-20 chip, which features an higher NIR QE and reduced fringing, for the redder part of the spectral range.
Figure 5.1 – Flat field fringing at 900nm (images and cut) at the UVES red CCDs (MIT is left).

The detector quantum efficiencies are very important in the overall instrument efficiency. The two arm concept allows that each chip can be optimized for the intended wavelength range, and will give better results than a single chip. In Figure 5.2 we show the efficiency curve comparison for MIT/LL and EEV2 CCDs. The impact of the detectors quantum efficiency on the overall instrument efficiency can be seen in figure 3.4.

Figure 5.2 - Efficiency curves for MIT/LL and EEV2 CCDs.
5.2 - CCD Mounting, Detector Head and Cryostat

Since in the new cameras design a standard dewar window can not be used (the focal plane is not located far enough from the last surface, i.e, the last camera lens will be the detector window) and because of that the dewar can not be shared with other instruments, we are considering the idea of using a smaller dewar than the one designed by CTIO for the SOAR imager, in order to best fit them in the optical bench.

We intend to use also the CTIO dewars, but a smaller one or a customized design for STELES. The CCD controllers will be specified as the ones used in the SOAR optical imager and IFU spectrograph, to take advantage of the previous experiences in the CTIO development of these devices and to facilitate the integration with the ICS. The Goodman Spectrometer also needs a smaller package because of space constraints, and may use a CryoTiger.

Although the standard SOAR dewars should hold the temperature stable for ~30hs a smaller CTIO one still can have a hold time well over 12 hours, and filling at the start of the night will generally do for the whole night. Is important to note that the STLES dewars will not move at all.

The SOAR CCD mount design is be a copy of that designed and built by NOAO Tucson for the WYNN Mini mosaic The CCD will be mounted accurately at the dewar front face using techniques developed for the NOAO Mosaic For SOAR the specifications are much less stringent due to the slower beam.
Figure 5.2 - The SOAR Imager dewar detector head and mounting.
6 - Mechanical Layout

6.1 - General Description

The optical design is optimized to be built with no moving optical parts, an important advantage for an unattended instrument. Apart from the positioning of the transfer lens, only additional small auxiliary devices need to be adjusted as a function of the observing program. STELES will have 9 moving auxiliary devices, most of them not having critical aspects for alignment, operation or maintenance. The main auxiliary devices are: the main spectrograph shutter, fore-optics light buffer, field derotator motor, filter wheel changer, dichroics changer, 2 slit motors and 2 detector shutter motors (for more detail on motors see Sec. 8). A constrain driven by the UV capability choice is that the instrument have to be fed by the Nasmyth focus directly and do not use optical fibers. That means that the instrument should be mounted close to the telescope.

6.2 - Weight and space envelope

SOAR was designed to carry a total payload of 7400kg – 3000kg at each Nasmyth port, 300kg at each of the 3 bent Cassegrain ports, and 500kg for the bench spectrograph. With the present set of instruments it was already approaching those limits once the weight of the ISB/ISC's is included. In discussions with SOAR team they find that it would take a more detailed analysis to determine the exact amount of weight still allowed and the possible impacts on the lifetime of the bearings and motors. Thus their suggestion is that for the purposes of the conceptual design we aim for a total weight of no more than 1000kg.

As the moment is much more of an issue than the weight, the vertical position, which puts the weight as close as possible to the azimuth axis, is preferable. Being fixed on the telescope fork, STELES could be permanently installed, not competing in volume with the other Nasmyth instruments and still having enough stability to be used for moderate precision radial velocity studies. "As far as the space envelope is concerned, for this position, the corner of the platforms for the Bench spectrograph and Azimuth electronics racks at the base, and the Nasmyth platforms at the top sweep out circles as the telescope moves in azimuth are the further limits."

Being a thin instrument, STELES will fit mostly into the wedge-shaped volume bounded by the vertical side of the Yoke, the horizontal Nasmyth platform above, and the two slanting struts which support that (see Figure 6.3).
Based on similar instruments we believe that STELES will weight around 800kg, including the optical table (see Sec. 6.4.1), and much of the weight is fixed as close as possible to the vertical side of the yoke. In Figure 6.1 we show the proposed positioning of STELES on SOAR telescope.

Figure 6.1 - The proposed positioning of STELES on SOAR telescope.
Detailed weight calculations are being performed by Leg engineering based on the detailed mechanical designs and must be available in by December 10th 2003. The new optical design has shortened the lens/collimators diameters and consequently the supports weight.

6.3 - Fore-optics

6.3.1 - Pick-off prism

The STELES pick-off prism mounting system of in the ISB is very similar to the one used with the SIFUS mirror. Fernando Santoro is investigating the possibility of the stage placement in the ISB. The first simulations shows that the prism fits well in the position required, having only some movement restrictions, but the working position is free of conflicts. Considering the SIFUS mirror specifications we expect to have: 2 positions (In/Out), 180mm travel, repeatability = ±1.3µm, accuracy = ±18µm, resolution = 1.25µm, configuration time < 10 sec.

Figure 6.2 - View of the STELES pick-off prism on the optical ISB.
6.3.2 - Transfer Lens

The transfer lens will be mounted on a retractable linear stage fixed on the spectrograph bench, and will be positioned at the beginning of the mission.

The mounting and alignment of the transfer optics with the spectrograph will be a critical part on the mechanical design. Since it will be located around 1280mm far from the ISB box, a very stable mounting should be foreseen. Analytical calculations shows that the precision and repeatability of a THK linear stage is enough to fulfill the optical tolerances for this lens, so that the image on the slit do not move more than 5% (3 pixel) from one positioning to the other. After finite element calculations and simulations together with the ISB mechanism we can be able to analyze the need of an active laser system to keep the system aligned.
6.4 - Spectrograph

The spectrograph will be assembled on a single optical bench, customized to be fixed vertically on the telescope. The enclosure will cover all the optical parts and will leave the CCD dewars rear part in the outside in order to facilitate nitrogen filling operations. Four fixation points will be mounted on the telescope yoke to ensure the possibility of a correct alignment of the STELES bench. One will be fixed and three adjustable. The alignment of STELES will be done using the flat field light passing through a pin hole mounted on the filter wheel and reflected on the slit viewers.
6.4.1 - Optical Table

The optical table for STELES will have approximately 1.6m x 1.8m (2.88m²). As it will be positioned on the vertical and it may require a reinforced top plate, allowing the use of a thinner bench. The optical table structure is under study but probably will consist of 5mm aluminum skins enveloping a rigid structure filled with a 100mm aluminum honeycomb, with custom pattern hole for support fixation. Following the 100mm Dumped Honeycomb Tech Base density (66kg/m²) (information from Oriel Instruments catalog 2002) plus the rigid aluminum structure we will have a total weight of approximately 250Kg. Even in the case that the structure analysis shows that we need a thicker table we do not increase too much the table weight.

One heavy constrain on table and supports thickness is the very small distance from the center of the light beam to the telescope fork (~370mm) but the mechanical designs for the lens supports fits the supports and table in this space. Figure 4.15 shows the profile of the instrument and the space between the center of the light beam to the telescope fork.

6.4.2 - Optical Mounts

Most of the optical mounts for STELES can be adapted from similar spectrographs designs like FEROS and UVES, taken in account the different orientation of the bench. There some more challenges in the STELES mechanical design because of the very compact design, what means that the light beam crossing in the Littrow design leave very small clear space for the supports, but again we can take advantage of similar designs. For example: the small folding mirror that is placed between the echelle grating mounting and the beam coming to the second collimator - the Giraffe spectrograph team had the same problem and solved it gluing the mirror behind a DILVER-P mount (has the same expansion coefficient as the optical glass).

The echelle gratings will probably produce the grater contribution to the total stray light. This effect shall be minimized via baffles in the echelle mounting. Other baffles will be placed strategically to minimize as possible the stray light. In Figures 6.5 to 6.7 we show the concept for the optical mountings of STELES.
Figure 6.5 – Concept for the STELES optical mountings. Bafflers not shown.

Figure 6.6 - Concept for the STELES optical mountings. Zoom on the central part of the instrument
Figure 6.7 - Concept for the STELES optical mountings. 2D view.
Figure 6.8 - STELES optical mountings. Slit and slit viewers detail
6.4.3 - Camera, shutter and CCD dewar

Since if we use the standard SOAR dewar it can not be shared (see Section 5) we are considering the idea of using a smaller dewar than the one designed by CTIO for the SOAR imager, in order to best fit them in the optical bench.

We intend to use also the CTIO dewars, but a smaller one or a customized design for STELES. The CCD controllers will be specified as the ones used in the SOAR optical imager and IFU spectrograph, to take advantage of the previous experiences in the CTIO development of these devices and to facilitate the integration with the ICS. The Goodman Spectrometer also
needs a smaller package because of space constraints, and may use a CryoTiger. The dewar shown in the graphics is the SOAR imager dewar scaled down by 30%.

**Figure 6.11** – Collimator mounting and clamps based on the FEROS mountings.

The camera lens support is one of the most sensitive systems in the spectrograph. We also shall take advantage of the UVES design, which has very similar cameras, and adapt it to STELES specifications. The camera design must include also the shutters, since the distance from the last lens to the dewar windows are very small. The cameras mounting is foreseen to be assembled by the camera lens producer. Coastal optics and SESO prompted for quoting this systems since we have the final specifications.

### 6.4.4 - Enclosure

The enclosure shall cover all the optical parts and mountings, but will provide easy access to the CCD dewars to facilitate the refilling operation and connections. An easily deployable and dust-tight cover will be mounted and fixed on the optical table to improve the thermal stability. Following UVES (ESO) the enclosure panels will be constructed with two layers of 2 mm black anodized aluminum glued to a 25mm Polyurethane layer with a 20mm air space between them. Two doors on front side will give immediate access to the spectrograph mountings for maintenance.
STELES enclosure will have a temperature isolation system and will be maintained at a stable temperature using the cooling flow facility provided by SOAR, to compensate the heating by electronics and motors. The enclosure design should take this into account.

7 - Telescope Facilities

Bellow we describe the facilities provided by the telescope that will be used by STELES.

7.1 - Calibration Unit

The calibration unit will be mounted on the upper side of the optical ISB and will provide the instruments with emission line spectra for the wavelength calibration and a continuum-light source for flatfielding purposes. "Light from the lamps is first integrated in a reflecting hemisphere (concentrator) that directs the light from a calibration lamp efficiently into a beam of a controlled f-ratio. After 3 reflections light from the selected lamp arrives at the instrument focal plane, covering the 8 arcmin science field with a focused beam of quite uniform intensity at the proper f-ratio. A field lens at the exit of the concentrator locates the virtual pupil at the same distance from the focal plane as the telescope pupil to best simulate the telescope beam. Large-scale spatial variability in the field intensity should not be more than a few percent and may be very much less. Perfect absolute flatness is not necessary for making flat field exposures since, as long as they do not change with time, small non-uniformities are easy to eliminate during data reduction. The SOAR comparison system should be very stable because it has no moving parts other than the M3 flat and is relatively insensitive to misalignment." A Xe or Deuterium source may be desired for higher flux flat fielding in the UV (3000-3600Å).
Designs for projectors are already available with housings for hollow cathode lamps with, for example, a Th-Ar bulb. An ordinary hollow cathode Thorium–Argon lamp seems to be sufficient for wavelength calibration. However the filling gas Argon shows very strong lines in the red beyond 6700Å, so for appropriate illumination in the blue the detector is saturated in these red lines forming strong blooming features. For this reason we may follow FEROS approach and use a combination of a Thorium–Argon hollow-cathode lamp with the spectral region above 6700Å blocked by an edge filter and a Neon lamp to provide additional spectral lines in this red spectral region.

**7.2 - Atmospheric Dispersion Corrector**

The atmospheric dispersion correction is very important for STELES, considering that it is a slit spectrograph, specially in the blue side. H. Epps is designing the ADC under the coordination of C. Clemens (UNC). The prisms will be made of fused silica and it is being optimized for the 3200-11000Å range. The performance below 3200Å is not well studied, but it "should be fine at zenith distance of 30-40 degrees, but not so good at higher airmasses". For special observations on the 3000-3200Å spectral region it is desirable that the ADC can be deployed and this should be a requirement for the ADC mechanical design.
7.3 - Guiding Probe

The guide probe consists of a pick off mirror that can be positioned to pick the light of a guide star located within the patrol field re-image it on the guide sensor. The guide sensor shall have useful sensitivity over the wavelength range 400nm to 1000nm. Having a small field of view STELES can easily search for a guide star in the 8' probe field without field obstruction. The guiding accuracy required is driven by the slit width of ~ 1.0" to 0.6". See Figure 6.2.1 b.

7.4 - Electrical Power

The spectrograph movable systems will be based on Silvermax Smart motors, in accordance with SOAR specifications (see Sec. 6.1). The total power required for the 10 motors (Sec. 8) is estimated to be 200W, but most of them will be used few times in a run and only the derotator motor (20W) will be working continuously during the exposures. Besides the motors the only other power consuming devices are the 2 CCD controllers (see Sec. 5.5). This means a very low power requirement for the instrument. Electrical connectors, cabling, and conduit shall be defined in accordance with SOAR specifications and to be consistent with high reliability operation and EMC constraints.

7.5 - Cooling Flow

The STELES enclosure will be maintained at a stable temperature using the cooling flow facility provided by SOAR project to compensate the electronics and motors heating. The enclosure design should take this in to account (see Section 8.4).
The SOAR Telescope Echelle Spectrograph (STELES) project shall provide a modular Instrument Control System (ICS) to control each spectrograph sub-system and monitor its status and provide a user interface, in which all these modules are integrated in order to control all STELES sub-systems in standalone mode. SOAR shall be responsible for final integration of the ICS with the SOAR TCS.

The control system, besides controlling all the movable parts of the spectrograph, will be responsible for the integration of the instrument with the user, telescope, calibration unit and the other telescope facilities. We are using LabView to develop the control system and the SOAR libraries will be used to integrate it to the Telescope Control System (TCS). The control system shall include resources to control all the movable devices individually, or in combination under computer control.

In this section we show the present status of the development of the user interface, which is the front end for all the STELES ICS functions. It is designed to show the observer only the relevant information for the instrument operation. The software was developed so that two frames are always visible, with some operational status, the other functions are available in a “Tab” system, which contains one tab (or one frame) for each setup parameter. It implies in a simplified operation, as the user only accesses each function at a time, when it’s necessary. This design provides a clean and user-friendly interface screen.

Figure 8.1 – STELES ICS diagram
8.1 – Motors

All motorization will follow SOAR suggestion of using Silvermax Smart motors. This high performance servo motors have fully integrated design, with built-in motion controller, internal non-volatile program memory, master-slave operation. All these features mean that they can easily be integrated with the LabView ICS and TCS.

Figure 8.2 – The Silvermax Smart motor characteristics.

8.2 - Controlled Parts

The STELES optical design is optimized to be build with a minimum of moving optical parts, an important advantage for an unattended instrument. Only auxiliary devices need to be adjusted as function of the observing program.

The moving main optical components are: 1) the transfer lens, which is integrated in the fixed platform and is positioned by a linear stage in the beginning of the mission; 2) the field derotator; 3-4) the cameras focus.

STELES will have 8 moving auxiliary devices, most of them not having critical aspects for alignment, operation or maintenance. The auxiliary devices are: 1) fore-optics light buffer cover, 2) the main spectrograph shutter, 3) filter wheel, 4) dichroics changer, 5-6) 2 slit width control and 7-8) 2 spectrograph shutters.
8.3 - The ICS front end

The STELES ICS user interface is designed to show the observer only the relevant information for the instrument operation. It contains three sections: two fixed and one variable. One of the fixed sections is the status panel, where the status of the ISB position, of the light baffle tube, of the spectrograph shutter and the status of the STELLES Temperature Control system (STC) is shown. Once all these devices are ready, all the functionality of the STELLES will be available.

The other fixed section is the info panel, which provides information of the current exposures. In this panel, the user is able to check the remaining exposure time, the red and blue slit images, and also to monitor the centroid values behave, plotted on a graph that indicates the distance of the actual centroid from the center of the slit.

The variable section contains all the setup parameters required by the instrument to work properly. It is where all the main ICS functions are located, and is designed to operate in a “Tab” system, that means one tab (or one panel) is available for each setup parameter. The setup parameters, or the tabs, available are: setup, calibration, environmental control and alignment/guiding.

Each of these tabs is described below:

8.3.1 – Global view
Figure 8.3 – Global View of the user interface

The global view: the two fixed sections.

Figure 8.4 – Status Section and it’s interactions with the TCS, and Info Section

Figure 8.5 – Info Section
8.3.2 – Setup frame

The setup tab provides the options of filters (from 1 to 4), to set up the appropriate field derotation, starting from any start angle. And the speed of derotation: stop, sidereal or custom. Also the dichroic can be selected (A or B) and the width of the blue and red slits. This VI’s interaction within the whole ICS is described below.

Figure 8.6 – Setup tab

Figure 8.7 – Setup interactions
### 8.3.3 – Calibration frame

The calibration tab has input fields for the values of time and amount of each calibration type (bias, flat or thorium). Here, one can choose to perform a standard calibration, which values are already set. There are two status displays (estimated finish and current image), that informs the user of the status of the calibration process. Below, the calibration VI’s interactions with the telescope control system.

**Figure 8.8 – Calibration tab**

![Diagram of Calibration VI interactions](image)
8.3.4 – Science frame

The science frame contains the input set up fields for the science observation. In this panel, the user will input the exposure number and time of each exposure. There is also the possibility to set up a limit for the desired counts based on the photon counter. There are also commentary fields for the image: name, type, number on the sequence, path to save, title and extra comments for each image. The user can interrupt the acquiring process anytime, and choose whether to save or discard the current exposition. Below, it’s shown the VI’s interaction with the TCS.

![Science frame interface](image)

Figure 8.10 – Science tab
Figure 8.11 – Science interactions

8.3.5 – Environmental Control Tab

This task is described in more detail at section 8.4

Figure 8.12 – Temperature tab.
8.3.6 – Alignment, Guiding and Slit viewer frame

In this tab the user can perform two operations. The first is the alignment of the spectrograph optics using the flat field lamps passing through a pin hole mounted on the filter wheel. This task should be performed rarely. The second is to center the science object on the slit and perform a secondary guiding complementary to the one available on the TCS. The panel has the following functions: slit viewing, from both red or blue cameras; centroid position correction (manual or automatic), using the observed star or using an offset star.
8.4 – Environmental Control

Being fixed at the telescope pier, STELES will be exposed to the dome temperature variations. To maintain the spectrograph stability during the observations, besides the passive enclosure isolation system, STELES will be equipped with an active temperature control system to be maintained at a stable temperature; using the cooling flow facility provided by SOAR to compensate the heating by electronics and motors.
8.4.1 - Enclosure

The enclosure shall cover all the optical parts and mountings, but will provide easy access to the CCD dewars to facilitate the refilling operation and connections. The optical table is under study but probably will consist of 5mm aluminum skins enveloping a rigid structure filled with a 150mm aluminum honeycomb, with custom pattern hole for support fixation. An easily deployable and dust-tight cover will be mounted and fixed on the optical table to improve the thermal stability. Following UVES (ESO) the enclosure panels will be constructed with two layers of 2 mm black anodized aluminum glued to a 25mm Polyurethane layer with a 20mm air space between them. Two doors on front side will give immediate access to the spectrograph mountings for maintenance.

8.4.2 – Heating and cooling

SOAR estimates for Cerro Pachon temperature variations shows that we should expect operation temperatures in the range –10 to +25 degrees. No data is available about the air temperature variations with time, but they should be less than 2 degrees per hour during the night. SOAR dome has its own thermal regulation, based on 6 ventilation/refrigeration units mounted around the dome, so we shouldn’t expect fast temperature variations due dome-exterior gradients.

The spectrograph movable systems will be based on Silvermax Smart motors, in accordance with SOAR specifications (Section 8.1). The dissipated energy of each motor was measured to be ~3W/hour, but most of then will be used few times in a run and only the derotator motor will be working continuously during the exposures. Besides the motors the only other significant heating devices are the 2 CCD controllers (see Section 5.2).

The STELES temperature balance between the external temperature variations and the internal heating will be maintained stable by means of the cooling flow facility provided by SOAR. The detailed enclosure design will take this in to account with pipes, winded on the internal panels, with a regulated fluid circulating through them. Besides the cooling efficiency two points should direct the cooling flow design: it is important to avoid any vibrations transmitted to the spectrograph when the thermal control system will be running, and to allow dismantling units and ensure the fine tuning of the thermal regulator these pipes-systems should be built in separable sections.
8.4.3 - Thermal Control

STELES ICS thermal control module (STC) will monitor, in real time, external and internal temperatures and, based on a thermal model, provide the actions to maintain the instrument temperature stable during the observations. The STC will be integrated with the Labview based Instrument Control System (SICS). The STC sensors will be installed in the STELES enclosure, but to avoid vibrations and more heat dissipation, the thermal controller for STC should be installed outside the enclosure on one of the SOAR electronic hacks.

A detailed thermal study of STELES to provide the best model for the STC is foreseen.

The mass of the instrument should help to maintain a good short-term stability filtering the high frequency temperature fluctuations.

A set of 8 temperature sensors will assure a fine control of regulated temperature at different points. Monitoring points will be defined by the STC model, but following other instruments definitions (for example: HARPS and SARG) probable points for sensor installation are: outside skin of enclosure, inside skin of enclosure, spectrograph bench, echelle grating mounts, camera mounts, and transfer lens support (that will be the enclosure/ISB interface). The first monitoring points of the list above will provide the most active part in thermal control. Besides these sensors the STC will have access all motors temperature (each motor has an integrated temperature sensor and to the SOAR thermal-fluid, dome and outside temperature measurements through the TCS.

8.4.4 – Control Electronics Equipment

The thermal control process will operate with its own specific close-loop electronic controller. Possible sensor are the RTD (model 29233-B-80 - www.rdfcorp.com) which have a temperature precision of 0.2 degrees. A set of this sensors controlled by a National Instruments module under Labview is under tests at LNA, to monitor the temperature variations at the 1.6m dome.

8.4.5 - Intended Performance

The STC final performance will be driven by the optimized optics tolerance analysis, which will set the maximum temperature variations allowed to maintain the spectral stability required for STELES. Estimate values based on other instruments are:
Enclosure internal set point absolute value: 20(??) °C ± 0.5 °C

Temporal fluctuations of the spectrograph temperature:

- Slow (night), accuracy / peak-peak: < 0.5 °C
- Fast (minutes, hours), accuracy / peak-peak: < 0.2 °C

Temperature gradient (homogeneity) across the enclosure: < 0.2 °C
9 - Instrument Simulation

The instrument simulation tools are important before and after the commissioning of the instrument. Before to help in the critical view of the design and test development and after the commissioning to help the user extract the best from the instrument. A raw data simulations and an exposure time calculator are being developed for STELES.

The raw data simulator will help in the development of the data reduction software and the exposure time calculator will help the estimates of STELES performance and will help the observing time proposals and preparation for the observing runs.

9.1 – Raw Data Simulations

The spectral format of both channels fits a 2048x4096 (15mm) pixels CCD (30.7mm wide, 61.4 mm high), with 71 blue orders (84 to 154, from 300 to 500 nm) and 38 red orders (88 to 52, from 530 to 900 nm). To best fit the 2D spectra in the blue CCD the dispersion direction will be in the 2048 pixels direction, and in the red CCD in the 4096 one. The order separations are in the range of 9 arcsec to 20 arcsec in the blue channel, and 8 arcsec to 19 arcsec in the red channel, allowing good sky subtraction for a 1 arcsec seeing spot.

The data simulation was performed using IRAF’s noao.artdata.mkechelle package based on the spectrograph parameters and the efficiency tables described in the section 9.2. Some differences were found between the IRAF and ZEMAX simulations probably because the IRAF task was designed for reflection gratings and not for VPH gratings and further efforts are needed to improve the veracity of the artificial data. The main difference is that the order separation gradient is more step in the IRAF simulations than in the ZEMAX calculations, yielding very tight blue orders (that is the main concern about the data reduction). But the small differences do not prevent the use of the images for the data reduction software development.

The model includes all spectrograph parameters, data sampling and stray light models, but do not include the wavelength dependent transmission of the instrument or customized models for grating blaze functions. The model uses standard blaze functions profile that could be fine for the echelle but not for the VPHs. Photon and detector noise values should be implemented based on the choice made.
In Figure 9.1, we show the STELES echellogram for the blue CCD and in Figure 9.2a and 9.2b a cut in the direction perpendicular to the dispersion. Note on figure 9.2b the simulated high sky brightness with a 7" high slit.

Figure 9.1 – STELES blue echellogram

Figure 9.2 – a) STELES spectral format simulated data - blue channel across dispersion. b) Same as a), but now zooming the first orders.
The same information, now for the red channel is show in figures 9.3, 9.4 and 9.5. In figure 9.3, we show the red CCD spectral format. We can note that, in this case, the dispersion is along the long side of the CCD (4096). In figure 9.4, we show the 38 red orders in a view across dispersion direction and in figure 9.5, we show a cut along the dispersion, where orders, 52, 62, 72 (strongest) and 82 are shown.

Figure 9.3 – STELES red echellogram

Figure 9.4 – STELES red echellogram across the dispersion.
9.2 – The Exposure Time Calculator

9.2.1 - Introduction

Besides the Instrument Control and Data Reduction softwares an Exposure-Time Calculator (ETC) is also foreseen for STELES. It will help the observing time proposals and preparation for the observing runs. Given the observation parameters, the necessary time to achieve a specified S/N will be computed as a function of wavelength. The ETC follows the data reduction software philosophy and is based on IRAF and Python. We present the design of the STELES ETC and the first results obtained using the theoretical efficiency values of the STELES components. After the commissioning of the instrument, the theoretical values can be easily changed by the ones measured.

9.2.2 – The IRAF task SPTIME

The Image Reduction and Analysis Facility (IRAF) is a general-purpose software system for the reduction and analysis of scientific data. The IRAF system provides a good selection of programs for general image processing and graphics applications, plus a large selection of
programs for the reduction and analysis of optical astronomy data. The system also provides a complete modern scientific programming environment, making it straightforward for institutions using IRAF to add their own software to the system.

The Exposure-Time Calculator (ETC) uses the spectroscopic exposure time package, SPECTIME, which consists of a general calculation engine, SPTIME, and a collection of user or database defined IRAF scripts. The scripts are one type of user interface for SPTIME. Other user interfaces are Web-based forms and IRAF graphics/window applications. The user interfaces customize the general engine to specific spectrographs by hiding components and parameters not applicable to that spectrograph and guiding the user, through menus or other facilities, in the choice of filters, gratings, etc. However, SPTIME is a standard IRAF task that can be executed directly.

SPTIME takes an input source spectrum, either a reference blackbody, power law, or a user spectrum, a background "sky", observing parameters such as exposure time, central wavelength, seeing, air mass, and moon phase, instrument parameters such as aperture sizes and detector binning, a description of the spectrograph, and desired output. The output consists of a description of the observation, signal-to-noise statistics, and optional graphs and tables of various quantities as a function of wavelength over the spectrograph wavelength coverage.

SPTIME models a spectroscopic system as a flow of photons from a source to the detector through various optical components. It then computes signal-to-noise ratios from the detected photons of the source and background, and from the instrumental noise characteristics. The spectroscopic system components are defined at a moderate level of detail. It is not so detailed that every optical element has to be described and modeled and not so coarse that a single throughput function is used. Not all components modeled by the task occur in all spectroscopic systems. Therefore many of the components can be left out of the calculation.

9.2.3 - The STELES case

As the STELES will be coupled to the telescope mounting and fed by the Nasmyth focus, it is expected to be very stable and will have only one spectral configuration. This will simplify the configuration and the calculator implementation because only a few elements like the dichroics, filters and the slit width must be configured to the desired result.
9.2.4 – Instrument Component Efficiencies

- **Lens Material**

STELES lenses are mainly of fused silica and CaF$_2$ to ensure a high transmission on the UV range. All the pre slit and blue channel are of UV grade silica or CaF$_2$ as well as the reflection and derrotator prisms. The red channel includes other glasses as S-FPL53, PBH1.

- **Pre slit Optics:** The pre slit optics consists of a total reflection prism, a transfer doublet, the field derrotator, the dichroic and a doublet that focuses the light on the slit. The eight glass surfaces will be coated with a broad band multi layer coating as Unaxis Supertriolin that can be modified with reasonable losses (we estimated a 1% loss over the published value, which give us a mean value of 98.5% transmittance for the pre slit glasses) to reach the 300nm region (see Fig. 4.16). The dichroic efficiency is shown bellow. The total pre slit efficiency has a mean value of 84% calculated with Zemax.

- **Dichroics:** Two dichroics are foreseen for STELES differing only in the cutting wavelength (500 and 550nm) to permit the observer to choose the spectral region to be on the edge. The transmission and reflection efficiencies were calculated by Barr Associates and are show in figure 4.4.

- **Slit:** The slit losses are computed with the standard Spectime table that covers a reasonable range of widths x seeing values.

- **45° mirror and Collimators:** Due to the four reflections in each channel the mirrors should be coated with a high-reflectivity coating for the desired spectral ranges (300-550nm in the blue and 530-900 nm in the red). For the red mirrors (2 collimators and folding mirror) the Unaxis (former Balzers) Silflex VIS single-layer coating could be used. For the blue ones a modified version of Silflex or a SiO based coating should be designed. In any case efficiencies of the order of 98.5% could be achieved (see figure 4.17).

- **Echelle grating:** The curve provided by Spectra Physics (former Richardson Gratings) for its model MR 166-1 (R4, 41.67l/mm) gives a means diffraction efficiency of 72% on the working wavelength range.

- **VPH gratings:** Whasat Photonics provided Efficiency curves, which is in charge of producing the prototype STELES crossdispersers. Their new producing technique yields a very high efficiency over a broad band. In figure 4.8 we show the predicted efficiencies for the VPH gratings, reflection gratings and grisms.
- **Cameras and corrector lenses:** Since the lenses on both channels need coatings designed for narrower bands in comparison with the pre slit optics we expect transmittance of the order of 99%. For the blue channel we can use a slight modified version of Unaxis Iralin and for the red channel the standard Unaxis Supertribolin.

- **Detectors:** Since the STELES detector are not fully defined we choose to simulate two possible sets of detectors (EEV and MIT/LL), each one with one blue and one red optimized 4096 x 2048 pixels CCD. The EEV CCDs are slight better in the 500nm region while the LL CCD have almost twice the EEV efficiencies in the extreme blue and red regions (see figure 9.5). Figure 9.9 shows a signal/noise comparison of STELES using both CCDs in the 310nm region for a solar type star.

### 9.2.5 – Telescope and Sky Efficiencies

For the telescope we used the standard new aluminum curve and scaled it to match a more oxidized aluminum. We reached a mean value of 64% for the efficiency 3 mirrors SOAR telescope. Since we do not have the ADC transmittance curve we adopted a fixed value of 96%. We used the CTIO sky brightness table to simulate the SOAR sky at different moon phases.

### 9.2.6 – Spectrograph Efficiency

The total theoretical spectrograph efficiency (excluding detectors) is shown on the figure 9.5. These values are calculated with Zemax taking in account the glasses and coatings stated above. The total instrument efficiency including detectors, telescope and ADC is shown in figure 9.6. We should note that these numbers are obtained from the best theoretical spectrograph conditions.
Figure 9.5 – Comparison between the different STELES components.

Figure 9.6 – The total instrument efficiency including detectors, telescope and ADC.
9.3 - The ETC Web interface

The STELES ETC web interface is a software system designed to help the observing time proposals calculation and the preparation for the observing runs. The ETC user interface is based on the PHP scripting language, which is especially suited for Web development and can be embedded into HTML.

The web interface is a menu configuration that the user can set all the observation time data that are relevant to the result of the time calculation. The configuration parameters are the desired signal/noise ratio or total integration time in seconds, maximum time per single exposure, central wavelength of the observation, slit size, dichroic type, filter type, detector binning, seeing, air mass, lunar phase, source spectrum type, temperature for blackbody source, power law index, wavelength of source flux or magnitude, source flux or magnitude, type of units of source flux or magnitude and the type of the detector.

The built-in parameters are the spectrograph transmission table, telescope transmission table, crossdisperser efficiency table, aperture transmission table, sky table, telescope effective area, and other telescopes parameters, grating parameters, dichroics parameters, blue and red channel parameters, etc.

The PHP user interface communicates with a Python program that uses the Pexpect Python module. The Pexpect Python module is designed to change the program behavior from an interactive mode program to a batch mode program. The PHP script sends to the python program all the parameters necessary to the program execution that then calls the IRAF cl, all the parameters that were given by the user, the internal database parameters and the tables parameters are set in the IRAF SPTIME module, the output results tables are built and the results are sent back to the PHP script that shows it in the web page.

The output graphs are built from the results tables using another Python program using the Pexpect Python module. The PHP script sends to the python program all the graphics parameters, this program calls a program called Gnuplot, that is a command-driven interactive function plotting program that builds the graphics and the graphics are sent back to the PHP script which shows than in the web page. In figures 9.7a – e we show the web interface form and results display.
Figure 9.7a,b – STELES ETC web interface form.
Figure 9.7c – STELES ETC results display.
Figure 9.7d,e – STELES ETC results display.
9.4 – Exposure Time Results

Figure 9.8 – Signal-to-Noise ratio per spectral element at 600 nm at different exposure times. Parameters: Magnitude X Signal Noise:, Central wavelength = 6000 [Å], Slit width in arcsecs = 0.8, Dichroic = Dichroic A, Seeing (arcsecs) = 0.8, Airmass = 1.0, Lunar Phase = New moon, Source spectrum = Blackbody, Temperature (K) for blackbody source = 5700, Units of source magnitude = V, Detector = EEV

Figure 9.9 – Signal-to-Noise ratio per spectral element at 310 nm at different exposure times for both CCDs. Parameters: Central wavelength = 3100 [Å], Slit width in arcsecs = 0.8, Dichroic = Dichroic A, Seeing (arcsecs) = 0.8, Airmass = 1.0, Lunar Phase = New moon, Source
spectrum = Blackbody, Temperature (K) for blackbody source = 5700, Units of source magnitude = V

Figure 9.11 – Signal-to-Noise ratio per spectral element at different wavelengths for both CCDs. Parameters: Slit width in arcsecs = 0.8, Dichroic = Dichroic A, Seeing (arcsecs) = 0.8, Airmass = 1.0, Lunar Phase = New moon, Source spectrum = Blackbody, Temperature (K) for blackbody source = 5700, Units of source magnitude = V, Magnitude = 8
10 - Data reduction Software

10.1- Introduction

The data reduction package developed for STELES must be able to automatically receive and reduce the data obtained with the spectrograph. The on-line data reduction should be built to produce reduced data (automatically or semi-automatically) but should also be able to show quick checks and evaluation of the spectra.

It is also important to be based on a public and well known platform. We choose to use IRAF as it fits the requirements above and can be installed in most of the usual operational systems. This point means that all users can have access to the code and that it requires little training for the users and the technical support team. A multi-institutional team is developing the data reduction package (as it is being done for SIFS spectrograph software).

The basic reduction procedure should be the standard for echelle spectra accounting for the particular characteristics of STELES data. The reduction package shall include: flat-field correction, order definition, echelle blaze function definition, stray light extraction, background subtraction, sky subtraction, optimal order extraction, wavelength calibration, order merging, correction for the instrument response function, graphical user interface and data-archive facilities.

10.2- The software basics

The Steles data reduction software (SDRS) is being designed as a pipeline for automatic reduction of data obtained with STELES spectrograph. It will take advantage from stability of the instrument in order to reduce intervention of the user to a minimum.

SDRS will be constructed in a platform which will take advantage from the widespread package (IRAF) and it will use mostly standard echelle procedures. Thus, most of the routines will be adapted from standard IRAF echelle tasks. On the other hand, the link of these procedures and the Graphic User Interface (GUI) will be written in PHYTON and PHIRAF, because of its versatility.
SDRS is intended to be fully automatic and online. At the end of the process, the observer will have a 1D calibrated spectrum and some statistical information about the reduction and data quality.

SDRS will work together with the instrument control system (SICS) and the image acquisition software (provided by SOAR). SICS will be responsible for managing the spectrograph configuration and send these information to the acquisition software. This software creates file headers and manages image transfer from CCD memory to the workstation hard disk.

The reduction process could be separated in two main blocks: calibration data preprocessing and science data reduction. The spectrograph is expected to be stable enough (see section 4) to allow the calibration data be obtained and processed during the afternoon.

10.3 - Reduction Procedure

Due to STELES standard echelle spectral format, IRAF echelle reduction routines can be used to reduce the STELES data, allowing the user to reduce it online, using SDRS or using his/her own preferred reduction technique.

Before release the software, many tests will be done in order to optimize the reduction process. In particular, the best curve fitting method, the optimal number of offset and calibration poses will be determined and used.

As depicted above, the steps that will be implemented in SDRS follow generally the standard echelle reducing procedure: In short, data are corrected for offset and cosmic ray hits. They are flattened, optimally extracted and finally merged. In the following subsections, we will make a brief description of each one these steps.

10.3.1 - Cosmic ray extraction:

The extraction will be made using IRAF task noao.imred.crutil.cosmicrays. This task detects and replaces cosmic rays by an average of four neighbors. First, the brightest pixel of a detection window (5x5 or 7x7) is identified. After this, the mean flux of the surrounding pixels (without the second brightest pixel) is calculated and compared with the brightest pixel. If this is above a previously specified threshold, it is replaced by the average of he four neighboring pixels. The threshold depends on the signal to noise ratio of the image and generally assumes a value 5??above the background.
10.3.2 - Offset:

A set of zero level images is combined using IRAF task `noao.imred.ccdred.zerocombine`. The images are combined by weighted averaging or medianing. The output image will be substracted from all other images, including calibration files, using IRAF task `noao.imred.ccdred.ccdproc`.

10.3.3 - Bad pixel correction:

From bad pixel mask obtained previously. The bad pixel mask will be constructed using IRAF task `noao.imred.ccdred.ccdmask` using a ratio of several reduced flat field images of different exposure times. This task identifies and attributes non-zero values to bad pixels. Subsequently, the bad pixels in the object images are replaced using the constructed mask by means of linear interpolation considering the mean intensity of neighbors pixels.

10.3.4 - Flat-field correction:

A set of flat field images is combined using IRAF task `noao.imred.ccdred.flatcombine`. After combination, we should correct the images applying flat field corrections. When using an echelle grating, it is not advisable to do a straight flat field division, because of the sharp profiles generated in the flat field and object images. In order to avoid bad edge effects, we will use IRAF task `noao.imred.echelle.apflatten` which model both the profile and overall spectrum shape and remove it from the flat field leaving only the sensitivity variations. After that, one should run task `noao.imred.ccdred.ccdproc` in order to divide them for the combined and flattened flat-field.

If simulations show that a better flat fielding is required an internal flat unit can be proposed for STELES. Unpolished glass can be inserted in front of the cameras so that the CCDs are feeded with uniform light with no order separation (exposure times will be increased considerably).

Concerning fringes, they are apparent with the EEV2 at wavelengths beyond 6000 A, and becomes worse as one goes further into the red. However, careful flat-fielding can reduce this to tolerable levels; for instance, dividing the spectrum of a standard star by a flatfield image taken immediately afterward could reduce the fringe amplitude at 7500 A from 20% p-p, to 4% or less (EEV2 CCD42-80-5-904 Test, 2001, Chris Tinney, AAO).

10.3.5 - Order definition:

In order to get this procedure working automatically the software will use a reference image, corrected for night-to-night variations. This procedure will allow aperture definitions
even for faint objects. The corrected reference image will be used then in task noao.imred.echelle.apfind. The standard procedure is to locate maxima across the dispersion direction and discard weaker peaks that are separated by less than a value previously defined. A maximal number of peaks are maintained and their centers are found. After that, a curve fit along the order is done using IRAF task noao.imred.echelle.aptrace. The best fitting method will be evaluated based on simulated and similar spectrographs data.

10.3.6 - Scattered light correction:

The scattered light outside the apertures defining the two dimensional spectra is obtained, smoothed, and subtracted from images using IRAF task noao.imred.echelle.apscatter.

10.3.7 - Order optimal extraction:

Uses Poisson statistics of photons in order to extract a 1D spectrum from a 2D spectrum. This method assigns different weight parameters for each pixel, taking into account that a pixel, which has a low signal, should have a low weight parameter. This is done estimating the variance of each pixel by a noise model based on the gain and readout noise parameters of the CCD detector used and a smooth profile function. The related IRAF task is noao.imred.echelle.apsum.

10.3.8 - Wavelength calibration:

In order to get this procedure working automatically the software will use a pre-identified image as reference image for identifying the lamp features in the current night images. This routine will make use of IRAF tasks noao.imred.echelle.ecidentify and noao.imred.echelle.dispcor. Initially, the calibration spectra obtained by the observer are compared with the reference calibration spectra, in order to adjust for night-to-night variations. After that, calibration spectra are pre-reduced as object spectra were (bias subtracted, flat-field divided, etc.). Remarkable features are identified and compared with the database lines, and a dispersion function is fitted. The reference spectra is then assigned to the object spectra using task noao.imred.echelle.refspec.

10.3.9 - Blaze correction:

Spectrum correction for the echelle blaze function. Task noao.imred.echelle.continuum.
10.3.10 - Order merging:

Merges different order spectra, interpolating them, if necessary, in order to get a uniform spectrum in the dispersion direction. Uses IRAF task `noao.imred.echelle.scombine`. Special attention should be taken in this procedure, in order to avoid “stairs” in the final spectrum.

10.4 - Data Format and Archiving

At the end of the automatic reduction, the observer will have at his/her disposal all raw data files (bias, flat-fields, calibration and science spectra) and the automatic reduced 1D spectrum. All intermediate files, such as averaged bias, etc., will be erased at the end of the reduction and only the relevant statistical information will be recorded together the reduced data. In Table 8.2, we summarize the data format we will have.

<table>
<thead>
<tr>
<th>File format</th>
<th>fits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Raw files</strong></td>
<td>bias, flat-field, bad pixel mask, calibration lamp and object</td>
</tr>
<tr>
<td><strong>Intermediate files</strong></td>
<td>averaged bias, averaged flat, 2D spectrum, 1D spectrum for each order</td>
</tr>
<tr>
<td><strong>Reduced spectra</strong></td>
<td>calibrated 1D spectra</td>
</tr>
</tbody>
</table>

10.5 - Graphical User Interfaces

Interactive graphical interfaces will allow the user to quick check either the raw or the fully reduced data. For raw data, the visualization tool will be PYRAF version of IMPLOT and for 1D data we will use Specview interface also from PYRAF distribution.

Specview is a Java application for 1-D spectral visualization and analysis of astronomical spectrograms. After the object acquisition phase, the raw science image will be displayed automatically and just after the online reduction term, a counts versus wavelength plot of the calibrated 1D spectra will also be displayed. The observer will have at his disposal simple tools for checking the data quality and manipulating his data as, for example, axis manipulation (changing of coordinates, annotations), zooming, fitting and production of hard copies. In Figure 8.6 we show one example of this tool, showing a screen shot of Specview with a 1D spectrum from the object NGC3516. It is shown the Lyman α region, in a flux density versus wavelength plot. It can be noted the several options to change visualization of the data as, for example, smoothing and fitting tools and zooming. Below the main panel, it is shown the multi instrument...
(wavelength) spectrum, from which the Lyman $\alpha$ region was extracted. This property from the GUI permits the observer to inspect closely his/her results.

Figure 8.6 – Screen shot view of the GUI Specview. In this figure, a 1D spectrum is showed for the object NGC3516. Image extracted from http://www.stsci.edu/resources/softwarehardware/specview/images/example2.
11 - Maintenance Concept

Since the STELES will work in a fixed configuration with few auxiliary movable parts only few time for the instrument setup is required. Therefore, to maintain the instrument performance during operations a small amount of maintenance work is needed. In the Operations Manual all required routine maintenance operations will be identified. The procedures for this maintenance as well as all special tools and supplies shall be identified in detail. This includes re-alignment and calibration in the case that a component requires removal and replacement.

A list of critical spares including all relevant information regarding, model, vendors, and recommended spare stocking strategy will be provided as well.

12 - Safety Aspects

During the setup of the instrument, the operation, and the maintenance work, a small number of safety aspects have to be considered to avoid hazards to the human personal.

In this sense, the following list refers to items with critical handling:

The optical bench is a heavy and large component and therefore requires a particularly careful handling during the set-up phase. Especially the transport and fixation up to the telescope yoke has to be considered. Further heavy and sensitive optical components: echelle + mounting, collimators + mountings, and camera/CCD unit.

The handling of liquid nitrogen for the dewar refilling must be in accordance with the common operation instructions.

No electrical hazards are expected since all the electrical components of the instrument operate in low currents and voltages. Anyway critical points will be adequately labeled.

All components of the bench-mounted part of the spectrograph will be permanently fixed onto the bench with clamps. Therefore, no moving or dropping heavy mechanical components will be encountered during potential earthquakes. A specialized simulation for earthquakes will be contracted to identify any potential weak points in the mechanical structure and fixation.
13 - Management Plan

13.1 - Introduction

This document contains the management information for the SOAR Telescope Echelle Spectrograph (STELES) Conceptual Design Review. This includes costing and planning information as well as information about the Laboratório Nacional de Astrofísica (LNA) of the Ministério de Ciência e Tecnologia (MCT) and its staff involved with the project.

LNA has produced a conceptual design for STELES and this management plan proposes costs and time estimates for building this instrument.

These are not final estimates, but are intended as a start point for detailed negotiations. All costs are quoted in United States dollars.

Due to the Brazilian Economical Variations, our Management Plan is based on an expectation that the funds required to build the instrument will be approved in a reasonable time scale, and the Project Team could have good management conditions over this resources.

13.2 - Work Breakdown Structure (WBS)

The WBS chart, Figure 1, shows the first two levels of the Work Breakdown Structure for the project.

13.2.1 - STELES Critical Design Study

During the Steles Critical Design Study, the optical design is to be finalized and the mechanical design is to be completed for the production of manufacturing drawings. The mechanical design is already contracted to LEG Engenharia Ltda. Full assembly drawings of the spectrograph are to be produced when the optical design has been optimized. These drawings will be used for flexure and thermal analysis.

The VPH gratings are already contracted to Wasatch Photonics in USA. The deliver is estimated to be 13 weeks after the first payment.

The optical design is about to completion by Dr. Bernard Delabre (ESO). Final adjustments and calculations are to be made by beggining of 2004.
The Software development is being done by a joint effort from LNA, ON, UESC and UFSC. Part of this team has already experienced working together at the SIFS Spectrograph.

Control system team has also begun to work on the ICS concept. Since the Steles Spectrograph has a few moveable parts and the motors are very well known because of their use at the SOAR Telescope and instruments, and the team has also acquired experience with SIFS, we expect few risks on the ICS development.

13.2.2 - Optics

LNA will subcontract the manufacture, assembly and test of the new Dewar for the STELES Spectrograph to CTIO. Other parts will be contracted from internationally recognized companies. These contracts will have a close supervision of a LNA specialist to get the best quality as possible.

Are included in this work package lenses and assembled cameras, echelle gratings, dicroics, colimators and VPH gratings. The contracts will have great importance to the mechanical fabrication due to the optical elements sizes and tolerances.

13.2.3 - Spectrograph Manufacturing Phase

We are planning a short and intensive construction phase to reduce the risk of fabrication delay due to unexpected variations in workshop staff availability and the impact of other Brazilian economical variations.

The mechanical parts will be contracted to a high qualified company to ensure quality. The most probably is to contract LEG Engenharia, due to the high professional work at the design phase.

Software and Control System are already under construction. Preliminary fluxograms are prepared and the work is divided into 3 main tasks (Data reduction, Control and Time exposure calculation). Programs will be based in “on the shelf” softwares (IRAF, Phyton and Labview). There will be contributions from UFSC, UNIFEI, IAG and UESC. There are not any “labor” costs for this work, exception for trips and meetings.

The user and maintenance manuals will be prepared to be delivered together with the instrument.
Figure 13.1 – The Work Breakdown Structure (WBS)
13.2.4 - STELES Assembly and Testing

Following rectification of any problems during the spectrograph construction phase, it can be integrated. The main objectives of assembly is to verify the optical alignment, software and control system check-out, calibration measurements, etc.

The plan is to have all the components at LNA to make the trial assembly. After rectification of problems encountered a corrective alignment will be repeated and the instrument shall be mounted.

After all tests, a safety transport will be provided to take the instrument to Chile.

The assembly and test work package budget therefore contains a contingency for an extra rectification.

13.2.5 - Commissioning

After transportation to Chile (La Serena), key acceptance tests should be repeated to check for transportation damage. STELES can now be transported to the summit and connected to the various interfaces to integrate it with the observatory systems. It can then be prepared for commissioning on the telescope.

Training for SOAR operations and maintenance staff will be provided, the manuals will be updated and the record documents will be finished.
13.3 - Schedule

An overview of the schedule for the STELES development is depicted in figure 13.2. A fully detailed Gantt chart appears in Section 13.8.

![Gantt chart](image)

Figure 13.2 – Overview of the schedule for the STELES development

13.3.1 - Milestones

The proposed milestones for this project are shown in table 13.1 bellow.

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual Design Review (CoDR)</td>
<td>November, 2003</td>
</tr>
<tr>
<td>Project Design Review (PDR)</td>
<td>May, 2004</td>
</tr>
<tr>
<td>Funds Approval for construction</td>
<td>January to May, 2004</td>
</tr>
<tr>
<td>Acceptance Tests</td>
<td>June, 2005</td>
</tr>
<tr>
<td>Delivery at Pachon</td>
<td>November, 2005</td>
</tr>
<tr>
<td>Project Closeout</td>
<td>December, 2005</td>
</tr>
</tbody>
</table>
13.3.2 - Spectrograph Critical Design Study

The Critical Design Study will terminate with the Project Design Review. The date of review is driven by the work to be done and the availability of suitably qualified and experienced staff to do it. Mechanical design is on the critical path. Completion of the design phase is planned for March, 2004.

13.3.3 - Optical fabrication

The Dewar design and fabrication is planned to be made at CTIO. All other optical parts will be contracted from recognized companies. The lenses delivery is one of the main time consuming task of the construction together with the detector system. It is estimated in 8 months for the lenses and 10 months for the Dewar/CCDs.

13.3.4 - Spectrograph Manufacturing Phase

The lenses and detectors will be the limiting factor to keep this phase to a minimum length, as long as the optical manufacture can be started early. All optical and mechanical parts will be subcontracted and the LNA specialists will closely follow all the steps of the construction.

The mechanical construction presents a few challenges for manufacturing and by the contracted company estimation, can be well fitted in the construction time range defined by the lens/detector time schedule.

The software team has a previous experience with another instruments, such as Eucaliptus and SIFS.

Control System is a very simple part of the job because of the use of a known system. The only risk task in the ICS is the temperature control, but the team is already working on it and this can be completed in time.

13.3.5 - Integration and Tests

The integration of all parts at LNA will take at least three months, including subsystems assembly and tests. After this, will occur the first complete test to problem fixing such as rectification of mechanical parts and misalignments. After the opto/mechanical acceptance by
STELES team, some spectral tests can be performed using a SOAR simulator and optical fibers. Then the instrument will be packed and transported to Chile.

**13.3.6 - Commissioning**

Commissioning phase will start repeating the acceptance tests to check for transport damage. The instrument will then be transported to the summit and integrated into the observatory systems. We estimate about 30 days will elapse between the instrument arrival in Chile and the first night on the telescope. STELES will be tested, commissioned, and verified under various observing conditions during the commissioning nights, and any problems will be rectified. SOAR staff will be trained for the operation and maintenance of the instrument. The time taken will depend on the commissioning time made available and on the nature and seriousness of any problem encountered.

**13.4 - Costs**

As shown in Table 2, the total cost of STELES, including the detectors, is estimated in US$ 939,500.00.

<table>
<thead>
<tr>
<th>Description</th>
<th>US$</th>
<th>US$</th>
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<tr>
<td>Subcontracts</td>
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<td>Mechanical Design</td>
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<td>Mechanical Construction</td>
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<td>VPH Gratings</td>
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<td>Echelle Gratings</td>
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<td>Cameras</td>
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<td>Foreoptics and Mirrors</td>
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<td>Filters</td>
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<td>Dicroics</td>
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<td>Sensors</td>
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<td>Electronics</td>
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<td>Travel/Meetings/Transport</td>
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<td>CCD / Dewar</td>
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<tr>
<td>Contingencies</td>
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<td></td>
</tr>
<tr>
<td>Total</td>
<td>$939,500</td>
<td></td>
</tr>
</tbody>
</table>
13.4.1 - Labour

All staff involved will have the salaries payed by their institutions or science foundations grants. The labour costs will be computed by the fraction of time expended in the project but are not included in the spectrograph budget.

13.4.2 - Travel and Miscellaneous

The travel budget, as well the labour costs and cost for photocopying, printing, telephone, etc, will be payed mostly by the LNA annual budget and the institutions related to the project.

13.4.3 - Capital

A large part of the total STELES project cost is for the CCD purchase (US$ 360 K). The cost for all further items to be purchased for the construction comes to US$ 570 K.

13.4.4 - Procurements

The optical components where quoted at high qualified vendors, such as SESO (France), Coastal Optics (USA) and Harold Johnson (USA).

The Echelle Gratings were quoted at Richardson Gratings and the Holographics Gratings (USA) at Wasatch Photonics (USA).

The motors will be acquired from Quick Silver Controls Inc.

We have investigated two companies to furnish the Optical Coatings. Denton Vacuum (USA) and Unaxis (former Balzers) (USA/Germany) just in case the lenses producer would not provide the specified coatings together with the lenses.

13.5 - Resourcing

The LNA Instrumentation Committee has declared STELES the number one priority for the engineering sections after the completion of SIFS spectrograph. Nevertheless, our first experience with the SIFS spectrograph indicates that inadequate resourcing is the greatest risk to a project schedule, following late delivery of major externally sourced items like optical and detectors.
To cope with demands on the engineering sections, LNA sent a few years ago, a Mechanical Engineer to the CTIO facilities to achieve the Astronomical Instrumentation “Know How“. He would also assist in project management.

LNA has a specialist with enough detector experience to make an immediate impact, and its Electronic Section has a good team of engineers to contribute efforts to the STELES project.

The STELES project organizational hierarchy is shown in figure 2. The development effort for STELES is led by the Project Scientist (Bruno Castilho) who is responsible for the establishing the science mission and scientific requirements for the instrument and eventually for ensuring that the instrument will meet these criteria. A team of specialists formed by Mechanical Engineer (Fernando Santoro), Electronics Engineer (Francisco Rodrigues) and Astronomer (Clemens Gneiding) are responsible for the contracts supervision. The Project Manager (Célio Andrade) has responsibility for the development of a budget and a schedule for the project and then for the completion of the instrument within the constraints of this budget and schedule, at the same time maintaining quality standards.

Such a triple headed approach is considered appropriate for a project of this complexity and cost. All three key project personnel hold senior continuing appointments in LNA and have the skills and experience in a multi-disciplinary approach to telescope and instrument development necessary for the success of this project. They have worked with each other on various LNA projects over a long period of time.
13.5.1 - Key Personnel

The following scientists and technicians are nominated for functions within the management structure of the STELLES project.

Table 12.2 - Project Team

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI</td>
<td>Bruno V. Castilho</td>
<td>LNA/MCT</td>
</tr>
<tr>
<td>Science</td>
<td>Beatriz Barbuy</td>
<td>IAG/USP</td>
</tr>
<tr>
<td></td>
<td>Kátia Cunha</td>
<td>ON/MCT</td>
</tr>
<tr>
<td></td>
<td>Gabriel P. Franco</td>
<td>IF/UFMG</td>
</tr>
<tr>
<td></td>
<td>Verne V. Smith</td>
<td>U. Texas</td>
</tr>
<tr>
<td></td>
<td>Gustavo P. Mello</td>
<td>OV/UFRJ</td>
</tr>
<tr>
<td></td>
<td>Thais Idiart</td>
<td>IAG/USP</td>
</tr>
<tr>
<td>Project Team</td>
<td>Bruno V. Castilho</td>
<td>LNA/MCT</td>
</tr>
<tr>
<td></td>
<td>Germano R. Quast</td>
<td>LNA/MCT</td>
</tr>
<tr>
<td></td>
<td>Clemens D. Gneiding</td>
<td>LNA/MCT</td>
</tr>
<tr>
<td></td>
<td>Simone Daflon</td>
<td>ON/MCT</td>
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<tr>
<td>Optical Designer</td>
<td>Bernard Delabre</td>
<td>ESO</td>
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<tr>
<td>Optical Consultant</td>
<td>Robert G. Tull</td>
<td>U. Texas</td>
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<tr>
<td>Managing</td>
<td>Célio Andrade</td>
<td>LNA/MCT</td>
</tr>
<tr>
<td></td>
<td>Marília J. Sartori</td>
<td>LNA/MCT</td>
</tr>
<tr>
<td>Mechanics</td>
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<td>UNIFEI</td>
</tr>
<tr>
<td></td>
<td>+ Collaboration with</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vanessa Macahan</td>
<td>LNA/MCT</td>
</tr>
<tr>
<td></td>
<td>Consultant**</td>
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<tr>
<td>Control Systems</td>
<td>Francisco Rodrigues</td>
<td>LNA/MCT</td>
</tr>
<tr>
<td></td>
<td>Leonardo Delaflate</td>
<td>UNIFEI</td>
</tr>
<tr>
<td></td>
<td>Odilon Giovannini</td>
<td>UCS</td>
</tr>
<tr>
<td>Software</td>
<td>Antônio Kanaan</td>
<td>UFSC</td>
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<tr>
<td></td>
<td>Ricardo Sediyma</td>
<td>UNIFEI</td>
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<td></td>
<td>Marília J. Sartori</td>
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<tr>
<td></td>
<td>Jaqueline Vasconcelos</td>
<td>UESC</td>
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<td></td>
<td>Adriano Cerqueira</td>
<td>UESC</td>
</tr>
<tr>
<td></td>
<td>Maximiliano Abans</td>
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<tr>
<td></td>
<td>José Dias</td>
<td>UFRN</td>
</tr>
<tr>
<td></td>
<td>Cláudia Mendes</td>
<td>IAG/USP</td>
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<tr>
<td>Integration, Tests</td>
<td>Bruno V. Castilho</td>
<td>LNA/MCT</td>
</tr>
<tr>
<td></td>
<td>Antonio Cesar Oliveira</td>
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</tr>
<tr>
<td></td>
<td>Rodrigo Campos</td>
<td>LNA/MCT</td>
</tr>
</tbody>
</table>

† - Most of the listed personal are only partially dedicated to this project.
* - The Mech. Dept of UNIFEI can participate in some subsystems projects, yet to be defined.
** - A greater involvement of F. Santoro on this project depends on the SOAR ISB schedule.

During the proposal of this instrument to the SOAR community we received the Scientific Support of several colleagues (other than the ones listed above), which we would like to record here:

<table>
<thead>
<tr>
<th>Institution</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNA</td>
<td>Carlos A. Torres</td>
</tr>
<tr>
<td>IAG/USP</td>
<td>Antonio M. Magalhães</td>
</tr>
<tr>
<td></td>
<td>Eduardo J. Pacheco</td>
</tr>
<tr>
<td></td>
<td>Nelson V. Leister</td>
</tr>
<tr>
<td>ON/MCT</td>
<td>Ramiro de La Reza</td>
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<tr>
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<td>Thais Mothe</td>
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<tr>
<td>OV</td>
<td>François Cuisiner</td>
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<tr>
<td>UFRN</td>
<td>Josê Renan de Medeiros</td>
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<tr>
<td>UFMG</td>
<td>Domingos Soares</td>
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<tr>
<td>UFES</td>
<td>Roberto Ortiz</td>
</tr>
<tr>
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<td>Mariângela O. Abans</td>
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<td>Marcos P. Dias</td>
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<td>Jane Gregorio-Hetem</td>
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<td>Silvia Rossi</td>
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<td>Cláudio Bastos</td>
</tr>
<tr>
<td></td>
<td>Francisco Araújo</td>
</tr>
</tbody>
</table>
13.5.2 - Instrument Design

LEG Engenharia Ltda is executing most of the mechanical design, with assistance from the Project Scientist and Mechanical Engineer (Fernando Santoro) when required.

The Control and Electronics Engineer (Francisco Rodrigues) and his team, will execute most of the System Engineering at LNA. The Control and Electronics Team assigned to the ICS development at this project level is composed by Francisco Rodrigues (LNA), Leonardo Delefrate (UNIFEI) and Odilon Giovanini (UCS).

The STELES software effort will be conducted by the Project Scientist Bruno Castilho, Antonio Kanaan (UFSC), Jaqueline Vasconcelos (UESC), Ricardo Sedyiama (UNIFEI), Simone Daflon (ON), Maximiliano F. Abans (LNA), Marilia J. Sartori (LNA) and Adriano H. Cerqueira (UESC). Part of this team has previous experience working at the SIFS software. They will also undertake software coding.

13.5.3 - Manufacture

All of the optical components are identified and will be purchased from a qualified vendor who will also supply the quality control tests for the optics. The mechanical manufacture will be contracted from LEG Engenharia, and will have a close supervision from the Project Scientist, the Project Manager and the Mechanical Engineer, to ensure high quality.

13.5.4 - Integration and Tests

The Project Scientist, Bruno Castilho, will lead the integration and test effort. Clemens Gneiding will also be heavily involved. Software testing will involve the whole software team. Any other staff may be called upon for problem rectification.

13.5.5 - Commissioning

The Project Scientist, the Mechanical Engineer, the Control System Engineer and the responsible for Optical and Detectors make up the core team to support the commissioning of STELES. Experience during the preceding integration and tests phase may influence the choice of staff to send out to La Serena, Chile.
13.6 - Project Management

13.6.1 - Management Approach

The fundamental approach to management of the project will be based on quantitative schedule and estimation, incorporating quality control measures. Microsoft Project will be used to develop and monitor schedules and Microsoft Excel spreadsheets will be used to manage costs at the project team level. The LNA accounting system will be involved at a higher level. Computer based tools will be used to improve the efficiency of management and science communication.

The team will abide by the Quality Management Principle: a comprehensive and fundamental rule for leading and operating an organization that is aimed at continually improving performance over the long term by focusing on customers while addressing the needs of all stakeholders. The direct customer for STELES is the SOAR Telescope, but ultimately the research astronomer using the instrument. Many different groups within the SOAR partnership are stakeholders.

The team will use the “process approach” to lead to better use of resources and lower costs. The processes will be managed to meet requirements. Clear responsibility has been established for managing the project. Problems will be addressed by process improvement.

13.6.2 - Reporting

In line with standard LNA procedures, staff members report their time use to their Section Heads, who pass the relevant information to the project managers for project tracking. Any proposed expenditure on a project has to be approved by the project manager to enable him to control and track costs.

Together with progress information reported at regular meetings, weekly for STELES, this enables the project manager to complete and submit regular progress reports to external clients. For STELES this reporting is on a monthly basis both to SOAR and to the Brazilian Astronomical Community.
13.6.3 - Reviews, Checking and Testing

At LNA, formal design reviews are conducted for internal projects, which stand to gain from external input, and for externally funded projects as a customer requirement. Project progress meetings are regularly used to informally review designs as they progress. At critical points in the design cycle, peers or supervisors check designs.

Testing during the Integration, Test, and Commissioning phases is generally thorough, but is only formalized and fully documented for externally funded projects.

13.6.4 - Quality Assurance

LNA will perform the Project and Engineering Management in accordance with its standard Quality Assurance processes. Subcontractors shall work in accordance with relevant components of these procedures. These procedures cover the complete, integrated technical effort and incorporate all tasks to be conducted as part of that effort.

13.6.4.1 - Objectives

The purpose and objectives of these quality procedures can be summarized as follows:

- To explain and demonstrate how LNA will ensure control of the quality and integrity of all its activities related to the project.
- To outline the LNA quality system and show how the project will operate within this system and be compliant with the customer requirements.
- To provide for timely output of information from the quality assurance discipline and ensure that this is incorporated into the design, manufacture, procurement, and test activities with the minimum impact on cost or schedule.
- To provide for the detection of non-conformances or incompatibilities, and for timely and positive corrective actions.
- To ensure optimization of reliability and safety and the sound translation of the contractual requirements into design, manufacture, and test.
- To allocate suitably qualified personnel with the experience and training to provide control and supervision to ensure conformance with the contractual requirements.

13.6.4.2 - The LNA Quality System

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The Quality System is structured to provide an environment within which engineering and administration personnel alike may conduct their activities in a manner controlled by procedure rather than policing. Within individual projects, senior engineering personnel are selected to function as check authorities for day to day design review and inspection requirements. One person is assigned the responsibility of being the Project Quality Assurance Representative (QAR). The QAR has responsibility for the quality needs of the project and reports to the Project Manager in respect of these needs. The design and administrative infrastructures within which the team must operate are clearly defined.

Each project functions within the corporate quality system but depending on the nature of the work involved and the individual customer requirements it may be necessary to address project specific requirements. These specific requirements are addressed in the Project Management Plan, and/or Test Plan as appropriate.

13.6.4.3 - Quality Assurance Organization

Responsibility for the project quality plan and organization will reside with the LNA Project Manager. The Project Manager will appoint a Quality Assurance Officer for the project.

The Project Manager will be responsible for ensuring that this project complies with the requirements of the Statement of Work. It will be the responsibility of the Project Manager to implement any corrective actions identified within the project. Such corrective actions may arise as a result of project specific or general quality system audits or from a general observation. The Project Manager will have internal responsibility for the quality of the deliverable items.

13.6.4.4 - Reporting Arrangements

External and internal reporting on quality will be conducted on an exception basis. The Project Manager will be notified of any project quality non-conformance issues and corrective action requests that are discovered as a result internal audits or general observations of the team members. Details of significant problems or potential problems including non-conformances and corrective actions will be included in the monthly Project Manager Progress Report. Internally the team members will report any deviations in the equipment manufacture or design to the Project Manager when they are encountered.

13.6.4.5 - Quality Control of Sub Contractors
As part of the project quality control process LNA may conduct audits of a subcontractor quality system to ensure that there is compliance with the requirements of the contract. In addition to this LNA may perform inspections of the work in progress and deliverable items procured from a subcontractor to ensure they meet the quality requirements of the contract. LNA staff may also attend testing to be performed by a subcontractor as necessary.

13.6.4.6 - Quality Control of all Other Work Undertaken for the Project

All other work undertaken as part of the project will be subjected to standard LNA procedures. This covers all the critical aspects that will ensure compliance with the contractual requirements. Key features are:

a) planning of review meetings to ensure that throughout the project outputs are reconciled to the requirements of the customer and contractor;

b) the authorizing, recording, and implementation of changes to specifications and designs;

c) control and monitoring of procurement;

d) control and registration of documents;

e) configuration of documents and designs.

13.7 - The LNA

13.7.1 Capabilities and Facilities

Brazilian astronomy has grown up 10% a year in the last decade. This growth is in a great extent a consequence of the success of the first National Laboratory in Brazil, LNA/MCT, which operates a 1.6-m telescope and two 0.6-m telescopes at Pico dos Dias, Brasópolis, Minas Gerais.

In general terms the way Brazilian Astronomy looks like today has been sketched about 20 years ago. A visionary belief at that time stated that an all-purpose all-community telescope would be the path to the future. In the beginning of the seventies Muniz Barreto from Observatório Nacional and Abrahão de Morais from the University of São Paulo proposed the acquisition of a 1.6-m telescope with some instrumentation and the minimum infra-structure needed for operations. A federal agency, FINEP, funded the project.
Observatório Nacional (Rio de Janeiro), one of the institutes of CNPq was chosen as the natural manager for the project. The agreement ON/FINEP was signed on behalf of the Brazilian community on Sep. 5, 1972. The 1.6 Telescope saw light for the first time at Observatório do Pico dos Dias (OPD) on April 22, 1980. It was officially dedicated by CNPq in February 1981. The new facility became known as The Brazilian Astrophysical Observatory and it was administered as a Division of ON/CNPq until 1984. On March 13, 1985, CNPq created the National Laboratory for Astrophysics. LNA has been an autonomous Institute of CNPq since a Deliberative Council meeting on Nov 9, 1989.

Today LNA is an institute of the Ministry of Science and Technology (MCT), and by far, the most important provider of observational support for the Brazilian astronomical community. LNA supports several Post-Graduation courses providing the data for the MSc and PHD work. LNA's responsibility does not end at this point. The work already done qualifies the Brazilian astronomical community to go ahead with a perspective similar to the one foreseen twenty years ago. Now, the next step is spelled with two words: Gemini and SOAR.

To have the best participation on those partnerships, LNA is redirecting efforts to the Astronomical Instrumentation.

LNA is building a new complex of laboratories (electronics, optics and mechanics) to have, in a close future, all the capabilities to build and upgrade great part of its instruments and new ones. Depending on the Government support, this complex will be ready to work by the end of 2004.
## 13.8 Detailed Gantt Chart

<table>
<thead>
<tr>
<th>Task Description</th>
<th>Duration</th>
</tr>
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<tbody>
<tr>
<td>Initial Arrangements</td>
<td>49 days</td>
</tr>
<tr>
<td>Define Project Name</td>
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<tr>
<td>Specify Science</td>
<td>49 days</td>
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<tr>
<td>Technical Characteristics</td>
<td>19 days</td>
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<td>Material selection</td>
<td>15 days</td>
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<tr>
<td>Visibility for Multi-object Verification</td>
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<tr>
<td>Identify Optical Designer</td>
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<tr>
<td>Conceptual Design</td>
<td>168 days</td>
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<tr>
<td>Hire Optical Designer</td>
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<tr>
<td>Identify Mechanical Designer</td>
<td>3 days</td>
</tr>
<tr>
<td>Exchange info with Optical Designer</td>
<td>6 days</td>
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<tr>
<td>Science Details</td>
<td>8 days</td>
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<tr>
<td>Hire Engineer</td>
<td>9 days</td>
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<tr>
<td>Start of Software and Control Conceptual Design</td>
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</tr>
<tr>
<td>Start of Conceptual Mechanical Design</td>
<td>10 days</td>
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<tr>
<td>Start of Conceptual Optical design</td>
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<tr>
<td>First Team Meeting - RIOCON</td>
<td>1 month</td>
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<tr>
<td>Optical Conceptual Design Analysis - Echelle</td>
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<tr>
<td>Team Meeting - Conceptual Design Revision</td>
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<td>Documentation (arrangements for SOAR B)</td>
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<td>SOAR Board Meeting - Seller Payment</td>
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<td>Management</td>
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<td>Documents</td>
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<td>Personnel</td>
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<td>Tolerances</td>
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<td>Spot Diagram</td>
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<td>Simulation</td>
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<tr>
<td>El. Def.</td>
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<td>CCD Design</td>
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<td>Follow-up</td>
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<td>MECHANICS (FG EEP)</td>
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<td>Concept</td>
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<td>Optimization</td>
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<td>Tolerances</td>
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<td>Final Element Analysis</td>
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<tr>
<td>Simulation</td>
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<tr>
<td>El. Def. &amp; Drawings</td>
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<td>FARE Fund Approval</td>
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<td>102</td>
<td>Revision</td>
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<td>User Interfaces</td>
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<td>109</td>
<td>Verification Testing</td>
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<td>110</td>
<td>Commissioning</td>
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<td><strong>SOFTWARE</strong></td>
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<td>Instrument Simulator</td>
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<td>Physical Model</td>
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<td>114</td>
<td>Raw Data Simulation</td>
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<td>Exposure Time Calculator</td>
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<td><strong>Data Reduction Software</strong></td>
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<td>117</td>
<td>Scope Definition</td>
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<tr>
<td>118</td>
<td>Modeling</td>
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<td>119</td>
<td>Coding</td>
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<td>120</td>
<td>Ventilation Tests</td>
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<td>121</td>
<td>Commissioning</td>
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<td>122</td>
<td>Managing/Documentation</td>
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<td>138</td>
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<td>Verification Tests</td>
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<td>140</td>
<td>Transport</td>
</tr>
<tr>
<td>141</td>
<td>Commissioning</td>
</tr>
</tbody>
</table>
Some possibilities for future upgrades in STELES:

- Fiber link to the ISB Calibration unit for simultaneous wavelength calibration.
- UV optimized ADC, exchanging the SOAR one for special UV observations.
- Image Slicers or
- Microlens arrays substituting the slits.
- New crossdispersers for long slit, few order, spectroscopy
Appendix A – Spectral format tables

Spectral format of STELES channels calculated with R Tull’s code.

Table A.1 – Spectral format for the blue channel.

Table A.2 – Spectral format for the red channel.
Appendix B - Optical Design Options, Report by R. Tull (Sep 2001)

See PDF file - Steles-RTull_report.pdf - distributed electronically with this text.

Appendix C - Optical Design for STELES lenses

See PDF files distributed electronically with this text.