

Report of the September 8-9, 1988 Meeting of the IUE Signal-to-Noise Committee

October 20, 1988

This report contains updated recommendations to the IUE project which are a direct consequence of the progress achieved in addressing the previous recommendations for the near-term study put forth in the May 17-18, 1988 Signal-to-Noise meeting. This discussion follows the format of the initial report written by Dr. Jeffrey L. Linsky, Committee Chairman, 21 June 1988. In brief and as a review, these reports have been written to answer in a thorough fashion three main questions:

PART I What requirements should govern the creation of the final archive?

PART II What specific tasks should be done in the near-term in order to learn how to reprocess the data properly and efficiently before the final archive is created?

PART III What is a sensible implementation plan in terms of numbers of people and time in order to accomplish the tasks as described in PART II?

Part I

REQUIREMENTS FOR THE FINAL ARCHIVES

Further discussions during the recent Signal-to-Noise Workshop indicate that all the requirements for the archive suggested in the May 17-18, 1988 meeting remain basically the same. Two specific areas of concern have been emphasized for importance: Accuracy and Content of the Data Files.

Accuracy

1. GO Comments

- (a) Errors in the coordinates of IUE exposures must be corrected, particularly those objects acquired using blind offsets.
- (b) Ambiguities in exposure times need to be addressed (i.e., multiple exposures and trailed exposures).

The IUE Observatory will determine the most efficient methods of correcting these problems and will make the corrections whenever feasible. This task ultimately may involve a cooperative effort by the IUE Observatory and the original observers. Moreover, as the questionable comments originate with both US and non-US observers, any comprehensive attempt to correct the comments must involve an international effort.

Content of the Data Files

1. Rotated Photometrically and Geometrically Corrected Images

- (a) Investigation into producing a rotated photometrically and geometrically corrected image without significant degradation of the data. This would yield an additional benefit of providing what would serve as a line-by-line file for high dispersion IUE data. It has been suggested that this rotation could be accomplished in the initial extraction process, and perhaps transformed

to the proper wavelength scale in one step, reducing any additional smoothing of the data that might result in further interpolation steps.

- (b) If this file can not be constructed without serious data degradation, a line-by-line file should be furnished both for low and high dispersion IUE data in addition to the unrotated geometrically and photometrically corrected image.

2. Gaussian Extraction (GEX) and Optimal Extraction Procedures

- (a) A decision should be made soon whether either GEX or the Optimal Extraction will be incorporated into the production processing for the final archive.
- (b) Although no GEX or Optimally Extracted file would be generated for the archive for high dispersion images, a consequence of close inter-order spacing, efforts will proceed in developing software that can be used to apply these improved extraction techniques to archived high dispersion data for specialized post-processing.

Part II

HOW TO REPROCESS IUE DATA FOR THE ARCHIVES: RECOMMENDATIONS FOR THE NEAR-TERM STUDY

Although considerable progress has been made, especially by IUE project members, on answering a number of questions posed in the report of the May 17-18, 1988 meeting, further work is needed over the next year before the final decisions are made about the best method of reprocessing for the IUE archive. A subcommittee (Meg Urry, Ed Fitzpatrick, Dick Shaw, and Nancy Evans) put forward a list of further studies necessary. These were discussed and prioritized by the entire workshop. Each area in the following list is given a priority (in parentheses following the Roman numeral header). A and A' are top priority items, with A indicating studies which must be done before final decisions are taken on the techniques to be used in the reprocessing. A' represents a high priority study, but one which is not required to be finished before these decisions are made. Parallel items B and B' are studies which should be done but are lower priority. A few very high priority individual items are noted with an asterisk.

A full discussion of many of the areas of investigation was presented in the May 1988 recommendations. This report follows the same structure but concentrates on new tests or investigations which have grown out of recent work. In particular, sections V and VII represent primarily a continuation of the May recommendations.

I. Studies of explicit geometric correction (Priority A)

1. *Further comparisons of the explicit versus the implicit geometric correction are needed. As an important first step, one must show that the explicit geometric correction, as applied to low dispersion data, actually improves the signal-to-noise in real astronomical data. A comparison should be made between the three processing methods:
 - (a) found reseaux with explicit geometric correction
 - (b) predicted reseaux with explicit geometric correction, and
 - (c) implicit geometric correction (current standard processing).

The extracted spectra resulting from these schemes (a-c) should be compared using co-added spectra of an astronomical object. The spectra will be examined to determine if the apparent increase of S/N is real in cases *a* and *b* over that seen in *c*.

In order to study the “smoothing” of features in the geometrically corrected data, an artificial bright spot (delta function) can be introduced into the raw image, and the correction schemes (a-c) applied. Other test patterns should also be employed.

2. How frequently can reseaux be found in spectra? Does starting at predicted positions help?
3. Can the geometric correction and a rotation be performed simultaneously to reduce the smoothing of the data?
4. Should the ITF be rotated? Will this reduce processing time?
5. Should ITF's be made available in the archives?
6. Can finer sampling of the image and/or higher order interpolation of the geometrical correction be used to reduce smoothing?

II. Fixed Pattern Studies (Priority A)

1. *Differences between the recent De La Peña study and the Lund Observatory results need to be reconciled.
2. Further studies are needed in the identification of the fixed pattern in raw images, and its possible use as a fiducial for the geometric correction. Would improved pattern recognition techniques help? Can areas of high contrast fixed pattern (including “hot pixels”) be identified? Is a geometric correction based on the fixed pattern an improvement over one based on found reseaux? Many of these tests can be conducted on low resolution images.
3. Does the fixed pattern persist through all intensity levels?
4. How does the fixed pattern change with time? The six monthly UV floods should be used to explore this. Does the fixed pattern change linearly with time?

5. How is the fixed pattern found in the raw images related to the fixed pattern noise found in extracted spectra?

III. Is it valuable to interpolate the individual pixel ITF's with splines? (Priority B)

This is probably important for the first LWP ITF which has typically 1 image per level.

When the tests in I, II, and III have been completed, it should be possible to define the optimal scheme for geometrically and photometrically correcting images. At this point a number of science images processed using the current production processing and the proposed scheme should be used to demonstrate the S/N improvement. The proposed scheme should show S/N closer to the photon statistics limit when approximately 10 spectra of calibration stars are co-added. A test should also be made by co-adding spectra taken at similar THDA temperatures and different THDA temperatures to see whether using images taken at different temperatures can mimic the S/N improvement found using aperture offsets by Leckrone and Adelman.

IV. Investigation of the physical origin of the fixed pattern noise (Priority B)

V. Spectral Extraction (Priority A)

1. Optimal extraction is under development at STScI by Kinney, Neill, and Bohlin.
2. GEX is being developed collaboratively by Edelson and Berghoffen (University of Colorado), Thompson (Goddard), and Urry (STScI).
3. Testing of these two programs is proceeding along the lines of the recommendations of the May 1988 S/N workshop. In particular, tests of the two methods on a broad range of types of spectra (as detailed in the previous report) still need to be run.
4. A line-by-line file for high dispersion should be included in the archives. Users can then customize their extraction. A high dispersion line-by-line extraction package is desirable. (Priority B)

5. A low dispersion spectral extraction method to improve S/N needs to be finalized (for both GEX and the Optimal Extraction). In particular tests should be made to see how large the S/N improvement is and to find cases where both methods may be inapplicable. The processing time also needs to be evaluated for each method. Tests of well-exposed standard stars are needed to see whether flux is conserved under these methods, or whether recalibration is necessary.

VI. Annotation of the archive (Priority A')

1. Updating of the header and label information in older IUE images is required to reprocess the data.
2. Correction of inaccuracies in the header information (poor coordinates, wrong exposure times) is necessary for a reliable archive. This effort should be started now.

Many spectra of extended objects, including about 30% of the spectra taken of the Orion Nebula, are “serendipity” or “parallel” exposures made through the large aperture during the primary exposure. While the coordinates in both the image header and script refer to the primary observation, those for the secondary aperture are often missing or inaccurate. The problem is much worse for observations made during the early years of the IUE satellite (1978–1982). While it is possible to calculate the position of the secondary aperture to arcsecond accuracy from information in the observation scripts, it is impossible for observers at their home institutions to ascertain without contacting the often distant observers themselves for clarification. Since the quality of the science that is derived from serendipitous observations of extended objects depends crucially upon a knowledge of the correct position and orientation of the secondary aperture, we recommend that the position information for the serendipitous observations be included (or corrected) in the image headers.

In addition, many VILSPA (and some GSFC) image headers and observation scripts do not indicate the reference star (with its assumed coordinates) used for blind offsets. The reliability of an offset position is directly related both to the accuracy of the reference star coordinates and the size of the offset. We

therefore recommend that each US and European script and image header involving a blind offset should have as a minimum:

1. the name and assumed position of reference star,
2. the position(s) of the aperture(s) to arcsecond accuracy, and
3. an indication in the image header of whether the exposure was made in parallel, and whether the coordinates were calculated from the spacecraft orientation. We also suggest that Goddard and VILSPA should adopt a uniform script format.

VII. Wavelength Calibration (Priority A)

Investigations by Ayres should be continued as described in the May 1988 recommendations.

VIII. The IUE project should continue both the S/N studies and their other calibration projects. (Priorities A and A')

Part III

PROPOSED IMPLEMENTATION PLAN FOR THE IMPROVEMENT OF THE SIGNAL-TO-NOISE IN THE IUE DATA

Resources

The main elements needed to implement the "proposed" signal-to-noise enhancements are:

1. people - to develop the algorithms and write the software, and
2. computer hardware - used as a tool by the assigned individuals.

Since the last meeting of the Signal-to-Noise Improvement Committee (SNIC), the IUE Project has made the necessary arrangements to acquire sufficient personnel for the development effort. A total of approximately 3 FTEs are now working on the S/N problem; this was the number stated in the May 1988 SNIC recommendations.

The second element, computer hardware, was discussed briefly in the May meeting, however no recommendations were made at that time. At present, all the S/N work is being done on the project computer, a VAX 8350. As this machine is already heavily oversubscribed with current tasks, there exists an immediate need for supplementary computing resources in order to complete the S/N research and development work in a timely fashion.

It is necessary to consider the time it will take to actually reprocess the final archive once it has begun. Assuming approximately 30 minutes as a lower limit (current IUESIPS) to process each of 80,000 images with processing running 24 hours per day, the processing of the final archives would take about 4.5 years. A reasonable time for completion of the archive reprocessing is 3 years which is equivalent to 19 minutes per image. At this time it is not possible to accurately estimate the processing speed for our proposed improved S/N production processing; however, there is good evidence that

the CPU processing time per image will increase when additional processing requirements are added in order to improve the signal-to-noise ratio; a doubling of the processing time is likely. This would imply a very significant delay in completing the archives unless additional resources are found.

The need for an additional CPU for the S/N development work and future reprocessing is indicated for the following reasons:

1. The oversubscription of the IUE project computer and the impact on current IUESIPS processing and science analysis of IUE data at the RDAF.
2. The efficiency of the S/N algorithm development and subsequent software development is hampered by the overloading of the project computer, and thus the implementation period is increased.
3. After the S/N research and development work has been completed, the additional CPU would be used for the archive reprocessing simultaneously with the current project computer in order to reduce the total reprocessing time.

COMMENTS ON IMPLEMENTATION TIME:

The determination of the final algorithms and techniques applied to the archive depend upon

1. the geometric correction
2. fiducial determinations (reseaux and/or raw image fixed pattern identifications), and
3. the application of the ITF.

It appears that all other areas of development require less time. An initial determination should be made in 4 months and a final decision not later than one year.

REPORT OF THE JANUARY 26-27, 1989 MEETING OF THE IUE FINAL ARCHIVES DEFINITION COMMITTEE

May 15, 1989

1 Introduction

This Report contains the recommendations of the IUE Final Archives Definition Committee (formerly called the IUE Signal-to-Noise Enhancement Committee), which were developed at its third meeting held in Greenbelt, Maryland on January 26-27, 1989. These recommendations for the near-term study on how to create the final archives are meant to modify and supplement those presented in the reports of the earlier meetings on May 17-18, 1988 and September 8-9, 1988, and should be read in that context. This report, like the others, addresses three main issues. The first part will examine what requirements should govern the creation of the final archive, the second will enumerate the specific near-term tasks that must be undertaken in order to learn how to reprocess the data properly and efficiently, and the third will attempt to define a sensible implementation plan, in terms of the required number of people, computer resources, etc., in order to accomplish these tasks in a timely fashion.

2 PART I: REQUIREMENTS FOR THE FINAL ARCHIVES

Detailed guidelines for establishing the final IUE archives were presented in the report of the May 17-18, 1988 meeting and modified in the report of the September 8-9, 1988 meeting. What follows are additions and modifications to these requirements.

2.1 TIMELINESS: (This is a newly defined requirement)

1. Various concerns, both scientific and political, dictate that the final IUE archives be produced over a period of less than three years (30 months was our most favored interval), beginning no later than January 1991. The timely and accurate production of the final archives will require significantly more computer power than available to the project at present. (See recommendation in Part III).
2. Reprocessing of IUE data for the final archives should largely be done on images in inverse sequential order, since more recent observations generally have the most accurate headers and records. Problem images should be flagged and set aside for special attention and corrections without interrupting the reprocessing flow. In this manner the largest number of archived images will be processed in the shortest time frame possible.

2.2 SIGNAL-TO-NOISE IMPROVEMENT

1. Periodic noise, present in the raw data at 0.5–1.0 percent of the signal level, should be filtered from the ITF images and possibly from the raw science data as well.
2. Continuing study of the noise characteristics in the IUE cameras support the previous recommendation that the final IUE archives should be processed with an explicit geometric correction, although final judgement will be delayed until all tests, including tests of alternative schemes (see Part II, section 4.1) are completed.
3. There are indications that additional noise may arise due to the inadequacy of the bilinear interpolation used in the geometric correction of the UV-Flood exposures used to generate the ITFs. The use of more complicated mathematical functions, such as cubic splines, may reduce the noise in IUE spectra.
4. Mis-registration of the ITF grid with the science data image by more than 0.2 pixel results in a reduction in the signal-to-noise ratio (S/N) by up to a factor of 2 in the two-dimensional image. Therefore, accurate registration of the science data with the ITF should be done as accurately as possible using as many fiducials as are available, including fixed pattern, reseau marks, the fiber optic bundle grid, and camera artifacts.
5. We now expect a significant improvement in S/N in the majority of the final IUE archive images as a result of more sophisticated mathematical techniques developed for the geometrical correction and ITF generation stages of data processing. Consensus guiding principles are that (1) we should minimize the resampling of the data in the images, (2) we should obtain the best feasible registration between the raw images and the ITF, and (3) we should employ consistent treatment for the raw science data and the ITF data.
6. Tests comparing the optimal (OPT) and Gaussian (GEX) extraction methods with the current IUESIPS extraction have been performed on a small set of low-dispersion images, with the following general results:
 - For well-exposed images, OPT and GEX offer little, if any, improvement over IUESIPS.
 - For less-well-exposed images, however, both OPT and GEX can give reductions in point-to-point fluctuations in the resulting spectra of up to approximately 35 percent.
 - OPT employs a more general profile perpendicular to the dispersion, has been more successful in incorporating a realistic noise model, and seems to be faster than GEX in its current implementation.
 - GEX, which assumes a Gaussian profile, is likely to be more successful for some weaker images where it is difficult to fit the profile empirically.
 - For some very under-exposed spectra, or emission-line spectra with weak continua, both OPT and GEX are likely to fail.
 - When making comparisons, it is necessary to treat the background in a consistent manner.

Because the improvement in S/N of the GEX and OPT extraction techniques over the simple IUESIPS technique is poorly known, we cannot yet recommend the use of one special extraction technique over the other for the production of low dispersion extracted spectra for the final IUE archives. However, we support the inclusion of either a GEX or optimal extraction (both if processing time is not a problem) in addition to the current rectangular extraction for low dispersion point source images. Such special extractions cannot be included in the final archive products for extended sources, and may not be possible for high dispersion spectra due to problems of overlapping orders.

7. For high dispersion spectra there is no scheme developed or on the horizon for extracting spectra using either a GEX or an optimal-like scheme. In lieu of this, rotated, geometrically and photometrically corrected line-by-line images of the high dispersion spectra should be included as part of the final archive data products to permit users to perform their own special extractions and analysis. In addition, we encourage the IUE Project to develop an improved high-dispersion wavelength calibration for the final archives based on the more extensive and more accurate National Institute of Standards and Technology (NIST, formerly The National Bureau of Standards) line list for the Pt-Ne arc lamp used on IUE.

2.3 COMPLETENESS

In addition to all NASA and ESA/SERC images, the final IUE archives should include:

1. All available commissioning period images.
2. FES images.
3. Observer scripts (both on optical disk and on microfiche). All NASA and VILSPA scripts should be electronically scanned and available as bit-mapped images that are cross-indexed with the merged log.
4. Spacecraft commands and status information recorded on the history tapes (possibly in a readable form, such as ASCII records which could be accessed by remote users).
5. Intensity transfer functions (ITFs) for all epochs.
6. A depository for written material related to the history and development of the IUE project. The IUE documents and Newsletters should be placed in machine-readable form (i.e. standard text files). Of particular importance are the Camera and IUESIPS Manuals.
7. A map for each camera should be included of the known pixel defects, "hot pixels", and other known camera artifacts.
8. The FES counts in the merged log for VILSPA and NASA images should be included as the converted magnitudes may be inaccurate due to the degradation of the FES with time.

2.4 ACCURACY

Proper and convenient usage of data in the final IUE archives requires easy access to original and corrected information concerning each exposure. Some inaccuracies and erroneous information exist in the science headers of IUE exposures, particularly for exposures of semi-stellar and extended targets set up by blind-offset maneuvers. In addition, several useful items of information, such as position angle of the long axis of the large aperture, are not currently given in the headers.

With respect to the science headers in the final archives, the committee recommends the following guidelines:

1. The original science header should be kept intact as originally written.
2. Corrections and supplemental information regarding the exposure should be added as an appendage to the header, not as a replacement. This approach has already been implemented by IUESIPS.
3. During the production of the final archives, images in the "old" archives at NSSDC should be flagged to indicate that "final archive" versions of the images are available.
4. Work to identify the extent of the header errors should begin immediately. This problem increases with time due to the less complete record keeping at VILSPA and the aging of the IUE observers. In particular, records and scripts were not preserved as completely near the beginning of the IUE mission as today.

In addition, the IUE final archive database system should have a convenient and comprehensive search and request facility. The proposed format presented by the IUE Project should be adopted, with small amendments that may result from suggestions from the IUE user community.

3 FITS FORMAT FOR EXPORTING DATA FROM THE ARCHIVES TO USERS

[Note - This proposed new requirement was added by the FADC Chairman after the January meeting. It will be discussed at the April 1989 meeting.]

The IAU General Assembly in Baltimore adopted two resolutions (see Appendix A) recommending that the Flexible Image Transport System (FITS) become the standard for data exchange among astronomical institutes. The IAU has established a FITS Working Group to maintain and extend the FITS standards. The NASA Science Operations Branch Management Operations Working Group (MOWG) is advising all NASA flight projects to adopt this standard, and NASA has set up a FITS Support Office with the functions as also described in Appendix B.

The FITS format is becoming the standard for data transmission in astrophysics and should become the standard by which data are exported from the IUE final archives to users. Software and the RDAFs should be made compatible with FITS format data. The NASA IUE Project should prepare plans for presentation at the FADC meeting for the development of software to write magnetic tapes using the internationally accepted FITS format. Critical issues are:

1. Define appropriate key words for the header file.

2. Devise a format for the extracted spectral data that maintains the original wavelength sampling in order to not arbitrarily smooth the data (as would occur for a uniform wavelength sampling). The final FITS format must conform with the IAU-approved version of FITS.
3. The option to acquire data from the archives in the existing VICAR format should be available.

Note that the IUEFITS format, currently implemented at VILSPA and soon to be implemented at GSFC, is documented in ESA Newsletter No. 32 published in January 1989.

4 PART II: HOW TO REPROCESS IUE DATA FOR THE ARCHIVES: RECOMMENDATIONS FOR THE NEAR-TERM STUDY

During the January 1989 meeting it was clear that the IUE project had made considerable progress in addressing a number of questions and outstanding problems raised in previous meetings. Based on reports presented at the meeting, we have revised the recommendations made following last October's meeting. The following revised recommendations are given roughly in order of their priority.

I. Remake the ITFs.

- A. Construct an ITF in its raw geometric space (i.e. with minimal resampling).
- B. Calculate noise characteristics.
- C. Exclude cosmic ray hits and other artifacts.
- D. Retain higher precision.
- E. Fourier-filter the 2-, 4-, and 8-point signal and remove the periodic noise.

II. Improve the geometric correction algorithms.

- A. Refine the cross-correlation algorithm to determine shifts to subpixel accuracy.
 1. Identify all varieties of viable fiducials, including reseaux, camera artifacts, and fixed-pattern (FP).
 2. Find a means to determine subpixel shifts.
 3. Define a means of rejecting bogus pattern matches.
 4. Define how to implement the calculated shifts in a geometric correction routine.
 5. Determine the minimum background DN level where these techniques fail, and what default approach to take in that event (such as using predicted reseau positions).

III. Experiment with applying new ITFs.

- A. Use found fiducials whenever possible.
- B. Re-examine both explicit and implicit geometric adjustment.

- C. Examine improved geometric correction algorithms, including ones that would permit a simultaneous rotation with minimal resampling.
- D. Try to apply a photometric correction by interpolating both between ITF levels and spatially (to account for mean DN-level shifts) with a more complicated function than linear, such as splines.
- E. Determine whether the ITFs from one epoch can be applied to images from other epochs.

IV. Continue fixed pattern studies.

- A. Determine if the FP persists through all intensity levels.
- B. Determine how the FP changes with time (functional form).
- C. Determine how the FP found in the raw images relates to the fixed pattern noise found in extracted spectra. This analysis is of crucial importance and may be related to the physical origin of the FP.

V. Archive the annotation and label modifications.

- A. Solicit from GOs their records of blind offsets maneuvers and other useful information for the final archive.
- C. Define required data items.
- D. Develop and test the procedures and algorithms.
- E. Determine required manpower, hardware and software resources.
- F. Generate documentation.

VI. Improve the wavelength calibration.

- A. Investigate applying the echelle grating equation for an improved solution.
- B. Include the larger NIST list of more accurate wavelengths for lines in high-dispersion WAVECAL images.
- C. Improve and/or extend the current fit-parameters.

VII. Improve the spectral extraction algorithm.

- A. Develop and test a combined GEX and OPT spectral extraction algorithm for low-dispersion data. Determine precisely when this new algorithm will and will not yield improved results.
- B. Characterize scattered light from the inter-order background from high-dispersion spectra.
- C. Improve the background removal for high-dispersion spectra.

VIII. Physics of the spectrometer optics, cameras and detectors.

- A. Investigate beam-pulling effects.

1. Obtain partially-read, T-Flood test images with spectral data super-imposed, as well as WAVECAL images with a variety of exposure times.
 2. Measure the positional deviation of the spectral features from that expected from ordinary images to relate the magnitude of the beam displacement to the gradient in the DN level.
 3. Parameterize the effect and determine whether the ITF can still be applied to pixels with DN levels that deviate greatly from those in the immediate vicinity.
- B.** Investigate the image background.
1. Determine whether the photometric correction to images with high radiation background is accurate.
 2. Determine why artifacts in sky-background images are not removed in the photometric correction, and what should be done to remove these artifacts.
- C.** Analyze discontinuities in the raw images along the edges of the fiber-optic bundles.

4.1 DETAILED EXPLANATIONS OF THE NEAR-TERM OBJECTIVES

I. Remaking and Testing the Improved ITFs.

Based on the information now available, it is clear that a new means of creating the ITFs must be tested. Because of the limited time available, only one ITF for one camera should be reconstructed, and the best candidate is the SWP both because of its importance and because the challenge of applying the fixed pattern as a fiducial for geometric registration is greatest for this camera. This experimental ITF should then be used in tests of further refinements to the proposed processing (items II and beyond) to determine if the new ITF characteristics still lend themselves to such methods.

Procedure for creation and application of an experimental ITF.

1. Construct a new ITF in mean raw coordinates:

- The UV-Flood images that constitute the modern ITFs were obtained at nearly constant temperature, and therefore will align to < 0.1 pixel, even for the SWP camera.
- Exclude cosmic ray hits and other artifacts from each ITF level as the constituent images are summed. Simultaneously construct a noise model for each ITF level.
- Fourier-filter the periodic noise from each raw image.
- Use D. Shaw's idea for minimal resampling to account for residual tiny shifts at each level. Use bi-cubic interpolation to create a mean image for each of the 12 ITF levels. NOTE: this resampling is less severe than the full GEOM that is now done and would amount to nearly zero resampling for a camera like LWR, where the reseaux are known to move by less than 0.2-0.3 pixel.

2a. Correct each level of the ITF to the mean reseau positions of one of the levels, using bi-cubic spline.

OR

- 2b. Provide a file of found reseau positions, including rms X and Y scatter, for each of the 12 ITF levels to permit implicit mapping to the science images. Use a more complicated scheme than bi-linear to interpolate between adjacent pixels in each ITF level. (D. Giaretta will pursue this concept)

II. Improve the geometric correction algorithms.

Work should continue on studies of how best to do the geometric correction, although good progress has been made. Some questions include:

1. The improvement in S/N gained by doing an explicit geometric correction versus an implicit geometric correction. How does this change as a function of variables other than time (e.g., THDA)?
2. The relative S/N improvement when using found reseaux instead of predicted reseaux with the explicit geometric correction technique.
3. Can the fixed pattern (with current ITF and with suggested "new" ITF) be used for registration? Would improved pattern recognition techniques help? Would this supplement or replace registration with reseaux?
4. Quantify the improvement in S/N from using splines or some other higher-order interpolation scheme for geometric correction.
5. Can geometric correction and rotation be done in a single step and does this reduce the smoothing of the data?
6. Should the ITF be rotated before application to images?
7. In all cases, the amount of smoothing could be estimated by introducing an artificial delta function (i.e. one bright pixel) in the image prior to processing, and comparing with the processed image.

III. Experiment with applying the new ITFs.

- A. Re-examine both explicit and implicit geometric correction with the new ITFs.
- B. Experiment with a fitting function for interpolating between ITF levels, rather than the linear interpolation now used.
- C. Determine whether the ITFs from one epoch can be applied to images from other epochs.
- D. Test Procedures

1. Choose images with reseau marks at the nominal mean positions of the ITF marks for initial testing.
2. Spectral Data
 - a) Emission line object - AR LAC sum of 12 images
 - b) Sharp emission line object - NGC 2346
 - c) Continuum in the standard star BD+28 4211 - sum of 16 spectra
 - d) Pt-Ne WAVECAL spectra

Compare these spectra with current IUESIPS reduction in terms of S/N and spectral resolution.

E. Concluding thoughts:

The difference between the new techniques and the present system is mainly a more proper construction and use of the ITF. The exact registration of the data image with the ITF may be crucial to get better spectra by this more proper application of the ITF.

The use of reseau displacements to interpolate shifts at positions between the reseau is not straightforward in the raw (ungeom-ed) space, and will require some further careful thought.

IV. Fixed Pattern studies.

We should determine if the fixed pattern is time and/or intensity dependent. A key question is how the fixed pattern in the two-dimensional image is related to the fixed pattern noise detected in the one-dimensional spectra. This analysis is of crucial importance and may be related to the physical origin of the fixed pattern.

EVALUATION OF WORK OUTLINED IN PART II, SECTIONS I, II, and III: [The following statement was also emphasized in the previous committee report.]

When the tests described above are completed, it should be possible to define the optimal scheme for geometrically and photometrically corrected images. At this point a number of science images should be processed using a scheme that parallels the current production processing as closely as possible in order to quantify the S/N improvement. The proposed scheme should show S/N closer to the photon statistics limit when multiple spectra (e.g., of calibration stars) are co-added.

V. Annotation of the final archive (format, headers, etc.)

We feel that work on identifying the extent and frequency of header errors and an estimate of the required manpower to correct them should begin immediately. This problem increases daily due both to the aging of IUE observers, and to the relatively less complete record-keeping at VILSPA compared to GSFC, particularly during the early years (1979-1981) of the project. The project should contact all GOs requesting pertinent information on each of their observations which may only be available in their personal notes.

VI. Improve the wavelength calibration.

Wavelength calibration of high-dispersion spectra, one that combines a physical approach (considering the origin of distortions that contribute to wavelength inaccuracies) and a first-principles approach (going back to the grating equation) may provide substantially improved results.

- We should consider replacing the old, empirical polynomial representation for the dispersion relation with the real grating equation, i.e. parameterize the sinc function instead.

There are several advantages to this approach. A sinc function more closely approximates the real optical arrangement of the spectral orders, so that it is likely that the residuals between the predicted and actual wavelength positions will be much smaller than with a polynomial representation, even one of high order. Second, the fits could be improved by applying some prior knowledge of the spectrograph design, or some good prelaunch measurements, in order to restrict the range of (some of) the fitted parameters. Any remaining trends in the residuals, caused, for example by coma or astigmatism in the image field, might be eliminated with small correction terms to the fundamental formula.

- We should attempt to obtain more exposures of the platinum lamp calibration over a greater range of exposure times. Very long exposures will permit many of the weaker lines to be included in the calibration, whereas shorter exposure times will diminish the effects of beam pulling, and therefore yield more reliable positions for the brightest lines.

VII. Improve the spectral extraction.

It was suggested for the first time that, rather than contrasting the competing methods of GEX and Optimal Extraction for improving S/N, the best features of each can be combined into a single, hybrid extraction program.

Although implemented differently, OPT and GEX are quite similar in philosophy, and it seems quite possible to create a hybrid program which would incorporate the strengths of both. We recommend that such a hybrid program be developed. The program could be largely based on OPT, with the addition of a default profile for cases where the profile cannot be accurately determined empirically. The program should include cosmic ray and bad pixel rejection and a realistic noise model. Experiments should be undertaken to determine the best choice of the default profile (e.g. Gaussian) and the effect of errors in the assumed default profile upon the accuracy of the extracted spectrum. Some experimentation will also be necessary to determine how to make sure that the (program-determined) transitions between the use of empirically-determined and default profiles will be both smooth and uniformly flux-conservative. The May 1988 near-term study recommendations list a variety of types of spectra which should be used for testing.

In view of the need to coordinate the extraction program with the rest of the reprocessing software (construction of new, properly registered ITFs may have a significant effect on the details of the noise model used in the extraction, and the absolute flux calibration will need to be re-derived for spectra processed with this new extraction program), it seems appropriate that the hybrid program be developed within the IUE project.

Very little has been reported concerning extensions of such techniques to high-resolution IUE spectra. In view of the complexity of such a task, and the necessity to decide by September 1989 which software to use for the final archive, it is unrealistic to expect that a high-dispersion analog to the OPT/GEX hybrid can be developed. However, the issues raised in the May 1988 recommendations regarding the characteristics of the background in high-dispersion spectra should be pursued, since an inadequate understanding of the background may lead to significant errors in the final processed spectra.

Evaluation of high dispersion spectra obtained for revision of the ripple correction has revealed that systematic mis-registration of the spectral orders can result in 10-20 percent loss of light

from the gross spectrum (LWP), and in contamination of the off-order background by spectral light. The source of the mis-registration must be identified and corrected if the high dispersion data are to be suitable for even relative spectrophotometry. Correction of the error is needed before the ripple correction and high dispersion absolute calibration can be derived.

Near-term work should concentrate on identifying the source(s) of the mis-registration, and in determining the extent to which these sources can be by-passed.

- Evaluate the extent to which augmentation of the long wavelength spectrograph line library improves the determination of the location of the spectrum on the target (spectral registration). This effort will be in parallel with the evaluation of the improvement made in the wavelength scale.
- Evaluate alternate spectrum location algorithms which may be used to extract reliable gross and off-order backgrounds suitable for use in the ripple and absolute calibration analysis.

Longer-term work:

- Evaluate the extent to which the choice of geometric correction algorithm affects the spectral registration. This analysis will not begin until the geometric correction evaluation effort is complete.
- Evaluate the suitability of the current IUESIPS spectral registration algorithm for the LWP and other cameras.

VIII. Physics of the spectrometer optics, cameras and detectors.

Understanding certain physical characteristics of the spectrometers may help us in properly calibrating the IUE images. In particular, a few tests that will aid in understanding the nature of beam-pulling were discussed at the meeting. The first would involve a systematic study of the change in the positions of emission lines in high-dispersion spectra as the exposure time is varied over a large range. The second would involve obtaining composite, high-dispersion images of bright standard stars superimposed upon T-floods that had been partially read. In both cases it is important to determine the magnitude of the change in the positions of the spectral features, particularly near sharp gradients in the charge distribution on the images.

The question of whether the various proposed algorithms will also improve the S/N in images that were exposed during high radiation background has not been adequately addressed. While the background is often the dominate source of noise in IUE images, the application of the proposed registration algorithms for geometric correction might result in a poorer signal-to-noise ratio for these images compared to what already exists in the archive. At the heart of the matter is whether the pixel-to-pixel variation of the background caused by charged particles is similar to that from photons. If they are similar, the proposed algorithms will probably be universally beneficial, but if not, the techniques that measure the background pixel-by-pixel may be necessary to obtain the best S/N ratio for these images. This problem is sufficiently urgent that suitable images with large backgrounds should be identified and examined in the near future. If the proposed techniques are detrimental to the S/N in these images, alternatives should be explored so that the committee can consider other options.

The proposed work can probably most easily be performed by scientists not associated with the IUE project. Small amounts of money should be made available to them to defray their costs.

We recognize that geometrical distortions in the camera image are not necessarily smooth, but may contain abrupt discontinuities. Investigations described at this meeting and elsewhere raised the possibility that dislocations at the boundaries of fiber optic bundles may be present at certain locations in the image, and these anomalies may manifest themselves as discontinuities in the image in a manner analogous to the dislocations along an earthquake fault line. This effect is most evident in strongly exposed continua in the LWR camera at the longest wavelengths in low resolution mode. Time and resources permitting, we should experiment with a new geometrical correction scheme which treats each of the square fiber optic bundles as a separate domain with its own coordinate system and distortion characteristics.

5 PART III: PROPOSED IMPLEMENTATION PLAN FOR THE IMPROVEMENT OF THE S/N IN THE IUE DATA

A summary of the September 1988 recommendations of the Signal-to-Noise Enhancement Committee:

The main elements needed to implement the proposed signal-to-noise enhancements are: (1) people - to develop the algorithms and write the software; and (2) computer hardware - used as a tool by these people. The IUE Project is to be commended for making the necessary arrangements to acquire excellent personnel for the development effort. The computer requirements have not yet been addressed, however. There is a clear need for an additional CPU for the S/N development work and future reprocessing for the following reasons:

- It will improve the efficiency of the S/N algorithm development and subsequent software development, thus reducing the time required to learn how to implement the final archives.
- Provide a second CPU (after all the S/N work, including software development, has been done) for the final archive reprocessing.
- Reduce the oversubscription of IUE computational resources, and thus reduce the impact on current IUESIPS processing and science analysis of IUE data at the RDAF.

5.1 RECOMMENDATION FROM THE JANUARY 1989 MEETING

The following equipment is needed as soon as possible: VAX 3600 computer system; 500 Mbytes of disk space (minimum); and an image display device. The timeliness requirement suggests that a rental arrangement must be attempted since the procurement process is too long.

For a long range computing solution the VAXstation 3100 might be considered. These machines are relatively cheap, are faster than the existing IUE machine (a VAX 8350), and are capable of running VMS MIDAS/IUESIPS (though the image interface needs to be modified) and IDL.

6 Appendix A: Resolutions Adopted by the XXth IAU General Assembly (August 1988)

Resolution B1: Extensions to FITS

... considering the present situation of the transfer of catalog and table data in digital form among astronomical institutes; and noting that significant improvements in portability can be made; recommends that all astronomical computer facilities recognize and support the rules for general extensions to the Flexible Image Transport System (FITS) including the extensions for the exchange of catalog and table data as described in Astronomy and Astrophysics Supplement Series 73, pp 359–364 and pp 365–372 (1988).

Resolution B2: Working Group on FITS

... considering the high importance of the Flexible Image Transport System (FITS) for the exchange of digital data between astronomical institutes and astronomical archives; decides to form a Working Group on FITS to maintain the existing FITS Standards and to review, approve and maintain future extensions to FITS, recommended practices for FITS implementations, and the thesauris of approved FITS keywords.

7 Appendix B: Summary of Proposed Functions for the FITS Support Office

The objective of the FITS Support Office is to provide support in the use of the FITS format for data interchange among users and projects. This includes a service organization that will assist users in using FITS and that can validate FITS products to improve the degree of interoperability among systems exchanging FITS formatted data. It also includes using the experience of the services organization as input to the evolution of the FITS standard, and coordinating with the Consultative Committee for Space Data Systems (CCSDS) Standard Formatted Data Unit effort to register FITS with a control authority.

More specifically, the FITS Support Office will:

- Support an external FITS expert in the establishment of a document defining the current FITS Standard. Currently the FITS Standard is spread across many different publications and is difficult for implementers to understand. The external FITS expert is expected to be Don Wells.
- Provide support to users in the application of FITS. This will involve answering user questions on the use of FITS and the availability of software. Experience will be recorded for subsequent analysis.
- Participate in the FITS Task Force to evolve the FITS Standard based on user experience.
- Work with an external FITS expert in the design and implementation of software to validate the conformance of a data product to the FITS standard.