TOWARD MORE UNIFORM DATA

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INTRODUCTION

The increasingly demanding requirement for data which can be correlated between the many spectral channels of a given instrument and between instruments makes it necessary to address the uniformity of data from each sensor. The emphasis has often been on the specification of instruments more for their operational characteristics than for their scientific validity and uniformity. The process toward uniform data begins with the phenomenologists who must define the products in as clear terms as practical to an engineering oriented society. The qualities of an image (sounding, atmospheric characteristic, etc.) must be defined in terms of spatial, spectral, temporal, operational, and evaluational requirements. The many products developed from any one instrument makes this extra difficult when the requirements conflict and trade-offs must be made to satisfy most of the users but limit some by not receiving the full set of desired data.

To start the process, definition of terms and translation of requirements into instrument related terms are important. Some of this can be served by the project scientist who makes a career of translating the user's requirements and wish lists into a comprehensible set of sensors and instrument requirements. From there the instrument specifications need to include tight spectral definitions which force uniformity among instruments. The field of view, sensitivity, scan angle and other features can often be adjusted or correlated to compare instrument performance, but the proper spectral data must be built into the initial instrument. Other features of encircled energy, field of view, registration, dynamic range and radiometric sensitivity must be specified and, if maintained, increase the comparative accuracy of the instruments. Calibration then becomes the issue for each instrument. The end-to-end measure of spectral, spatial and radiometric performance should be carried out with uniform definitions, test conditions and data reduction methods. Both the instrument and test equipment should be subject to external calibration with standards which are translatable from instrument to instrument. New methods of carrying calibration to various instrument development sites for comparative analysis may be required.

The need for uniformity in cataloging, storing, and processing data is an issue all agencies are facing. The needs are obvious and the archiving, recovery and utilization of the data are being addressed by many diverse organizations. Common approaches will aid the user, and are important to the whole community. Although
all elements of commonality or uniformity cannot be attacked at once, the awareness of the issues and common intent will advance processes already in place or in consideration. The users and ultimately the public will gain from our effort.

DEFINITION OF TERMS

The world of atmospheric science is nearly foreign to an electrical engineer trying to develop an instrument which is expected to do some exotic set of detection and classification of parameters for some strange atmospheric phenomenon. In the same manner the quality of an instrument to have a good Modulation Transfer Function is totally lost on a user who is only interested in whether an image will indicate an upper cloud disturbance with other cloud features mixed into the scene. Somehow, in order to obtain the proper instrument, we need to come together to be able to translate the science, data collection, calibration, processing and distribution into terms which make good sense to the engineer. Can you imagine Galileo trying to tell his machinist that he needs an instrument which must see distant stars, but not be able to define how the instrument must be designed? Common terms such as precision, accuracy, field-of-view, scan swath, and channel are not consistently used or defined; the differences between major projects, military and civilian agencies, and between national organizations make this increasingly important and yet more difficult. We suggest that the organizations and agencies review the most common terms and publish them for general use. An example of an attempt to define the different aspects of precision and accuracy are given in Wyatt(1990). The AIAA Space Based Observation Committee on Standards Sensors Working Group is attempting, along with other groups, to establish definitions for many of the most difficult terms. The list of references provides some sources for term definitions. Similar effort is necessary in the definition of physical constants, atmospheric transmission, geoid definitions, and other reference values. Since there are many of these available, the selection should be made from a standard list rather than to have each project or agency developing their own set.

SPECIFICATION DETAIL

The ability for an instrument to produce the same data consistently over time, and for more than one instrument of the same type to have comparable data rests with the team defining the initial instrument parameters. In an electro-optical sensor similar to the HIRS or AVHRR there are several key definitions. Perhaps the most important is the definition of the spectral bands. If the definition is not complete the shape of the pass band could vary and the impact on signal interpretation or cloud definition could be grossly incorrect. As shown in Figure 1 the

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spectral transmission of AVHRR Channel 1 (0.55 to 0.75 micrometers) can be different for two instruments. In order to reduce the difference in a series of instruments the spectral characteristic of a band might be given as a central wavenumber which is the average of the energy between the 5% response points. An alternate approach might be to ignore the peak, and signify the center of the equal amplitude spectral points defining 90% of the total energy. Instead of a 50% peak value other percentage points might be used to indicate the nominal spectral bandwidth, such as the equal amplitude points enclosing 70% of the energy and another at 50% of the energy. The spectral differences between these points could then be used to define the sharpness of the pattern. In the AVHRR the spectral bandwidth is specified for the 50% level and for the 80% level. In addition, in order not to have greatly different rising and falling edges, the difference between the 50% and 80% wavelengths and between the 50% level and the 5% level are specified. A further improvement would be to require that no variation above the 80% peak value have ridges greater than 5% (or 10%) of the peak value. With these specifications, and limits on the integrated energy outside the 5% points, the uniformity of the output from instruments of a series may be compared. The merits of a peak-based system and an integrated energy system need to be discussed and a selection made which all of the sensor community will accept (or be directed to use). The program office and the instrument definition team must continually be aware of the variations in instrument specifications and the impact on products. In most cases these specifications cannot be tightened severely on the first instrument, but means should be available to tighten the requirements on later instruments of a series, even if increased component selection results.

Another specification which requires close attention is the optical field characteristic. In most cases the definition of encircled energy is most valuable for large area fields such as used on the HIRS. The definition of percentages of total energy contained in an area is best, such as 70% of the energy within the round (or square) area defined as the Instantaneous Field-of-View for the given spectral band. Then perhaps 85% of the energy should be contained within the area defined by limits of 1.25 of the field size in each axis and 90% of the energy should be contained within 1.5 of the field size. This prevents having to relate to "peak" values. Most optical systems for large fields of views can be adjusted in focus for maximum slope of the edges of the field pattern. This leads to the potential for defining the edge slope for the field, which would certainly aid overlay of column information of a sounder with more confidence. In the same calculation, the centroid for the field should be defined as the center of the integrated energy within the 50% pattern as defined above. Here again, experience may be the best teacher, and these definitions should not be too restrictive until the first instrument of a series is tested and its characteristics used to limit the variance of following units in that series. Figure 2 is an illustration of the definitions for a wide field of view.
instrument. In a scanned instrument with narrow optical fields, the specification of 50% of peak amplitude may be sufficient. Also, for narrow FOV instruments limitation on test methods may require less than optimal definition of field specifications. For an imaging instrument Modulation Transfer Function tests may be used to establish the optic quality, but the definition must indicate that the resulting values are to be taken at the output of the instrument, using whatever data system is in the unit, and that the values should be based on a sine wave contrast target having limiting resolution in lines per radian. In addition the MTF should be identified for specific fractional values of the limiting resolution. Here again, for comparison of different instruments the fractions should be consistent, such as 1.0, 0.75 and 0.5 of the limiting lines per radian. (A recent effort comparing GOES-I performance with VAS became bogged down because of the lack of uniform test requirements).

RADIOMETRIC TESTING

Final testing of radiometric instruments in chambers using blackbody targets for simulation of space and earth leaves many factors to be improved in terms of comparative accuracy and proper characterization. Concern for the calibration of the targets, the simulation of orbital conditions on the instruments and the methods for data reduction lead to several observations. Most of the detectors used in infrared sensors are quite linear with radiance. That is, until you take into account the effect of background radiance, the impact of high level radiance targets, and the stability of the detector, electronics and other variables. Key to the comparative analysis of radiometric instruments is the method to be used for calibration in orbit, and the characterization of those parts of the instrument which cannot be tested in orbit. The major radiometric factor then is nonlinearity of response. The two-temperature calibration in orbit cannot determine this. The chamber tests must make enough measurements to quantify the 1 to 5% variations. In a multi-channel instrument such as the sounder the number and spacing of chamber target temperatures may reach 15 before all the channels are properly sampled. Tests at fewer radiances may leave doubts for the data taken in orbit.

Since spectral characteristics are considered key to comparative analysis it is imperative to measure the spectral characteristics of the complete instrument before shipping to the integrator. As difficult as this may be, there is no substitute for the characterization of the complete system. Convolution of optic element test sample data and estimated and partially tested spectral filter characteristics from a manufacturer are not sufficient for end-to-end system calibration. The need for narrow band-high energy test systems should be addressed in the requirements and proposal stage and considered necessary for instrument delivery and acceptance. The use of HIRS spectral estimates over the past fifteen years without end-to-end system
testing makes much of the data evaluation suspect. We must insist on this as a system requirement.

VISIBLE CHANNEL CALIBRATION

In the past the AVHRR and HIRS systems had no on-orbit calibration for the visible (solar) channel. In the future the solar effects are considered important enough to require calibration in orbit. The method of calibration has been discussed and various methods tried in orbit. In general the use of the sun for calibration has been found difficult for stability, uniformity and accuracy. It is likely that enough space must be made available on the spacecraft for a partially hemispherical target with internal lamp sources and diode monitors. The stability of the source will depend most on the monitoring diodes. Protection from degrading solar input and contaminants must then be provided for launch and orbit. At the present the problems of solar calibration in the laboratory are being addressed with spherical test units having many quartz bulbs and probably too infrequent calibration at a standards laboratory. These tests are considered only about 10% accurate. An in-orbit test unit would probably be at least that accurate, with the possibility that the flight units could be compared to a standard master at NIST or NASA. Comparisons to a more elaborate sphere in the lab would then provide a better reference base for flight calibration evaluation.

INSTRUMENT TEST

Initial program planning provides for collection of data necessary to record the data, and print out the general performance and test conditions. Problems exist in the initial planning for archiving, sorting and recovery of ALL from the instrument and the ancillary test equipment. In addition the software is developed from requirements for data to meet the specification, and with less than desired concern for the evaluation and diagnosis of the instrument in test. The subject of software requirements on programs is usually left to the manufacturer. However, if the data were collected in a standard fashion, using the same units, and with some general plan for headers, titles and data processing, the integration into a spacecraft or in preparation of ground software and data recovery could be greatly improved. The EOS program has some of these features in place, perhaps other programs or agency-wide use of these standards would help us all. The assembly of data into data packages, methods of transfer to primes and users and methods for calibrating the data could all be partially standardized. The experiences of EOS Program, NASA EOSDIS program, JPL, SDIO, and others could be reviewed now that more experience has been gained, and some additional controls on data collection and processing be considered as an on-going improvement program.
EVALUATION OF LABORATORY DATA

The collection of reams of data in the laboratory can be a major problem to the test group, quality control, and to the evaluators. In most cases the key test data has certain factors which are trackable through the series of subsystem test, instrument test, calibration, and integration. Typically the value of input noise referred to the input can be estimated during the proposal, tested at component, board, subsystem and system level. Tracking this provides means to uncover problems before they become major problems. System response as radiance input per output counts will indicate the combined optic throughput and detector response. The amplifier gains can be estimated then measured to maintain common baselines. Stability of motor motion, such as once-around timing, can indicate potential motor or bearing problems. These kinds of trend data can follow the instrument to integration and orbit. These factors are often not identified until late in the development or test period, at which time some of the baseline information from component or subsystem test may not be available. Consistency of data sets, collection of all ancillary data, and storing of the data in formats consistent with all evaluators will aid program development and data utilization.

CONCLUSIONS

The value of initial consensus between users and instrument suppliers on the science requirements for the instrument (spectral, spatial, temporal) is very important to providing an instrument which can meet the quality expected and maintain a realistic performance, schedule and cost. The specification of standard definition of terms, test methods, data collection and processing need to be re-evaluated from time to time to continually make use of our best experience to improve future programs. In particular, tighter specification of spectral characteristics and the testing to verify these are considered key to comparative analysis. Many of the other instrument characteristics can be adjusted if necessary. The use of common calibration methods, comparative calibration of instruments and in-orbit calibration will provide a data set for analysis of instruments of a type and between types. The planning for data collection, trending, and output formatting in common with other instruments, programs and agencies will provide improved data bases for evaluation. From this we will make better use of our resources and be more able to utilize the systems for the intended application.

REFERENCES


Wyatt, C., 1990: Terms, definitions, and experimental basis for accuracy and precision of MSX-SPIRIT 3 and EDX-DX sensors, Space Dynamics laboratory SDL/90-060. Utah State University.

Figure 1  Spectral Response Variation

Figure 2  Wide Field of View Response
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