EARTH SATELLITE CORPORATION
(EarthSat)

1771 N STREET, N.W., WASHINGTON, D.C. 20036 / (202) 785-1123

November 16, 1972

E72-10205
CR-128470

National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Attention: Distribution

RE: Six Month Progress Report - SR #141:
ERTS-A, Snow Enhancement

Gentlemen:

Earth Satellite Corporation (EarthSat) is pleased to submit a progress report for the period of May 26, 1972 to October 31, 1972. To facilitate NASA's review, a consistent format has been adopted for all progress reports prepared by Geosciences and Environmental Applications Division.

A. TITLE: Facilitating the Exploitation of ERTS-Imagery Using Snow Enhancement Techniques (SR #141)

B. PRINCIPAL INVESTIGATOR: Dr. Frank J. Wobber

C. CONTRIBUTORS: Dr. Frank J. Wobber, Mr. Kenneth Martin, Mr. Charles Sheffield, Mr. Orville Russell, Mr. Roger Amato

D. SUMMARY OF ACCOMPLISHMENTS: A brief listing of the primary accomplishments during the initial six month period of the experiment are listed on the following pages by phase. Accomplishments are detailed by task in the TASK STATUS REPORT. (Appendix A)

PHASE I: PRE-LAUNCH PREPARATION

- Consultations were held with the scientific monitor, Dr. Paul D. Lowman on July 14, 1972 to report on the progress of the experiment and to modify the experiment approach.

(E72-10205) FACILITATING THE EXPLOITATION OF ERTS IMAGERY USING SNOW ENHANCEMENT TECHNIQUES Seminnual Progress Report, 26 May - F.J. Wobber, et al (Earth Satellite Corp.) 16 Nov. 1972 39 p CSCL 08L G3/13

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- Contact has been established with the USGS in Boston, Massachusetts and the Massachusetts State Geological Survey to facilitate geological data acquisition.

- All 1:24,000 (7 1/2') and 1:250,000 (1°X2°) topographic map sheets that include portions of the primary test area (Massachusetts and Connecticut) and secondary test area (Maryland) have been acquired. The 1:250,000 scale sheets will serve as base maps upon which weekly snow data will be displayed.

- All available geological quadrangle maps within western Massachusetts have been obtained, along with state geological maps of Massachusetts, New Hampshire, Vermont and Connecticut. All maps have been studied to determine lithological boundaries, and major structural trends.

- Photo index mosaics of recent (1972) 1:76,000 photographic coverage of the Massachusetts test area have been acquired to eliminate a requirement for supplementary (snow-free) aircraft coverage. Underflights are now needed during periods of snow covera.

- A preliminary field study was conducted in western Massachusetts to determine the abundance and accessibility of bedrock exposures and snow reference points and to identify fracture zones which might be detected using ERTS imagery. Bedrock samples were collected and correlated with rock units on existing geological maps.

- An introductory package (Appendix B) was designed to enlist the support of cooperative weather observers in western Massachusetts and Connecticut who normally do not report snow depth data. The package consisted of an introductory letter, a NASA Press Release summarizing the experiment, andExample Reporting Post-card to inform the observer of the anticipated extent of his commitment, and a Reply Postcard by which he could inform EarthSat of his intention to participate in the experiment.

- Snow Depth Reporting Postcards (Appendix B) have been designed and sent to those observers who signified their willingness to report snow depth data on a weekly basis.

- An introductory letter and press release have been designed to be sent to newspapers in low density snow data reporting areas for publicity purposes. Public participation in the experiment (in the form of snow depth reporting) will be encouraged to supplement the existing network of stations.

- Geofracture lineament maps have been prepared from interpretation of 1:500,000 scale radar imagery mosaics of Massachusetts and Connecticut. The map will be drafted into a final product and used to verify geological lineaments interpreted from ERTS-1 Imagery.

- A base photo map scale of 1:250,000 was chosen for displaying geological information derived from ERTS-1 image analysis. This scale was selected because of (a) its compatibility with existing state geological maps (b) quality constraints which limit enlargement of ERTS-imagery beyond this scale and (c) its compatibility with 1:250,000 USGS topographic sheets being utilized to graphically display snow depth information. Principal investigators who are also utilizing New England as a test area were contacted to promote information exchange and to suggest the use of a common (1:250,000 scale) base map scale for information display. Preliminary response indicates that this scale is appropriate for multidisciplinary information display.

- A Final Report Outline has been prepared (Appendix C). Sections of the final report are being written as the experiment progresses.

- ERTS simulation imagery of ERAP Area No. 1 (Feather River/Lake Tahoe area) has been analyzed, annotated and the results integrated into the paper[1] referenced below which was presented by the principal investigator (Appendix D).

PHASE II: FIRST LOOK ANALYSIS

- A preliminary Data Analysis Plan has been developed and submitted to the Technical Monitor for approval.

- A cloud-free ERTS-1 image (1062-15190-5 & 7) of the secondary test area (Maryland) has been analyzed and selected for commercial enlargement to a scale of 1:250,000. It will serve as a photo base map upon which lineaments may be mapped.

- MSS bands 5 & 7 appear to supply the greatest amount of fracture detail analysis. Complementary image analysis using both bands will produce the maximum data yield.

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[1] Wobber, Frank J., and Martin, Kenneth R. 1972. Exploitation of Aircraft and Satellite Imagery Using Snow Enhancement Techniques. Presented before the 24th International Geological Congress, Montreal, Canada. Note: Paper not yet available in final form and will be submitted at later date. Credit was given for NASA support.

- Analysis of ERTS-1 imagery indicates that a significant number of geolineaments can be identified within the Massachusetts test area. Overlays of frames with excellent lineament detail (e.g., 1077-15005-6 & 7[2/], 1077-15011-5 & 7, and 1079-15124-5 & 7) have been prepared (Figure 2).

- Initial enhancement of available ERTS-1 digital tapes has been undertaken as a preliminary step in the development of full-scale automated enhancement techniques. Specific operations which were conducted include edge enhancement, gray level adjustment and development of preferential direction printouts. More complete procedures will be employed in the enhancement of digital tapes for a sub-image area of frame 1005-15005 within the New England test area.

- A preliminary reconnaissance of early ERTS-1 snow covered imagery of Canada indicates that the utility of the snow enhancement technique will be confirmed when snow-covered imagery of the test areas becomes available.

2/ Band 6 was utilized in place of the band 5 print which had been over-exposed.

E. SIGNIFICANT RESULTS:

- Photogeologic interpretation of snow-covered ERTS-simulation imagery of ERAP Site #1 (Feather River/Lake Tahoe) provided significant new fracture detail which had not previously been mapped on available geological maps of the area (Figure 1).

- Analysis of ERTS-analog (Apollo, Gemini, Nimbus, etc.) and ERTS-simulation (aircraft) imagery;indicates that more complete fracture analysis can frequently be conducted on snow-covered compared with snow-free terrain.

- Analysis of ERTS-simulation (aircraft) imagery suggests that snow enhancement techniques are useful for the detection of certain land use features, e.g., areas of timber cut-over, which have differing snow retention capacities.

- First look analysis of ERTS-images (e.g., 1005-15005-5 and 7, 1023-15003-5 and 7, and 1059-15004-7) indicates that numerous lineaments can be mapped through systematic analysis of ERTS-1 imagery (Figure 2). Many of these lineaments probably represent zones of intense bedrock fracturing and could be future sites of high-yield water wells as well as areas of potential problems in excavation and construction.

- Commercial flying firms may realize cost benefits by extending the period (from snow-free into snow-covered periods) during which satisfactory images for photogeological studies can be acquired.

- Snow enhancement appears to be a simple and no-cost form of edge enhancement, i.e., it can be useful in place of costly electronic edge enhancement under some circumstances. It may also speed and simplify automated detection and mapping of fracture systems.

- Studies to date also suggest that the potential exists for extension of snow enhancement techniques to northern latitudes and areas of permanent snow cover where acquisition of geological data has often been limited.

F. PROBLEMS:

Analysis of imagery and basic data collection (maps, etc.) in the Feather River area have benefited work conducted in the Massachusetts test area, but have less overall benefit than if imagery in the principal test area had been used. A firm NASA commitment to overfly the Massachusetts test area is essential.

Unanticipated costs have arisen because:

- A functional snow depth reporting network, which is required to assess the influence of snow depth on fracture detectability is not available and had to be established. National Weather Service policy not to release the addresses of their cooperative weather observers has introduced the need for indirect (and hence more costly) contact through the NWS.

- A more intensive field effort will be required to validate the geologic origin of lineaments detected from interpretation of ERTS imagery, since up to date geological mapping in many quadrangles is only now in progress.3/

- Validation of lineaments through secondary methods (other than direct field observation) has required additional supplementary analytical effort, (e.g., more intensive analysis of radar mosaics) because available fracture data in the test area is lacking. Much current fracture data cannot be released because of USGS policy which states that, unpublished geologic maps or reports cannot be rendered unless open-filed.

G. RECOMMENDATIONS FOR TECHNICAL CHANGES: None.

H. CHANGES TO STANDING ORDER FORMS: None.

I. OVERVIEW OF INVESTIGATION:

Pre-launch preparations have focused on the accumulation of complete and comprehensive ground truth information to facilitate more effective analysis of ERTS-1 data. A snow depth reporting network within western Massachusetts and Connecticut has been organized with assisstance from the National Weather Service. Weekly snow depth data will serve to define the effect of varying depths of snow cover on the detectability of fractures.

3/ There is no doubt that structural data generated from this experiment will prove useful for geological mapping in this area.

Analysis of all available (Gemini, Apollo, Nimbus, NASA aircraft) small-scale snow-covered imagery has been conducted to develop and refine snow enhancement techniques. A detailed photographic interpretation of ERTS-simulation imagery covering the Feather River/Lake Tahoe area was completed; the 580-680nm. band was determined to be the optimum band for fracture detection. ERTS-1 MSS bands 5 and 7 are best suited for detailed fracture mapping. The two bands should provide more complete fracture detail when utilized in combination.

Analysis of early ERTS-1 data along with U-2 ERTS simulation imagery indicates that snow enhancement is a viable technique for geological fracture mapping. A wealth of fracture detail on snow-free terrain was noted during preliminary analysis of ERTS-1 images 1077-15005-6 & 7, 1079-15124-5 & 7 and 1077-15011-5 & 7. A direct comparison of data yield on snow-free versus snow-covered terrain will be conducted within these areas following receipt of snow-covered ERTS-1 Imagery.

Questions concerning this report should be directed to the undersigned at (202) 785-1123.

Sincerely yours,

Frank J. Wobber

Frank J. Wobber
Director
Geosciences and Environmental
Applications Division

FJW/lal

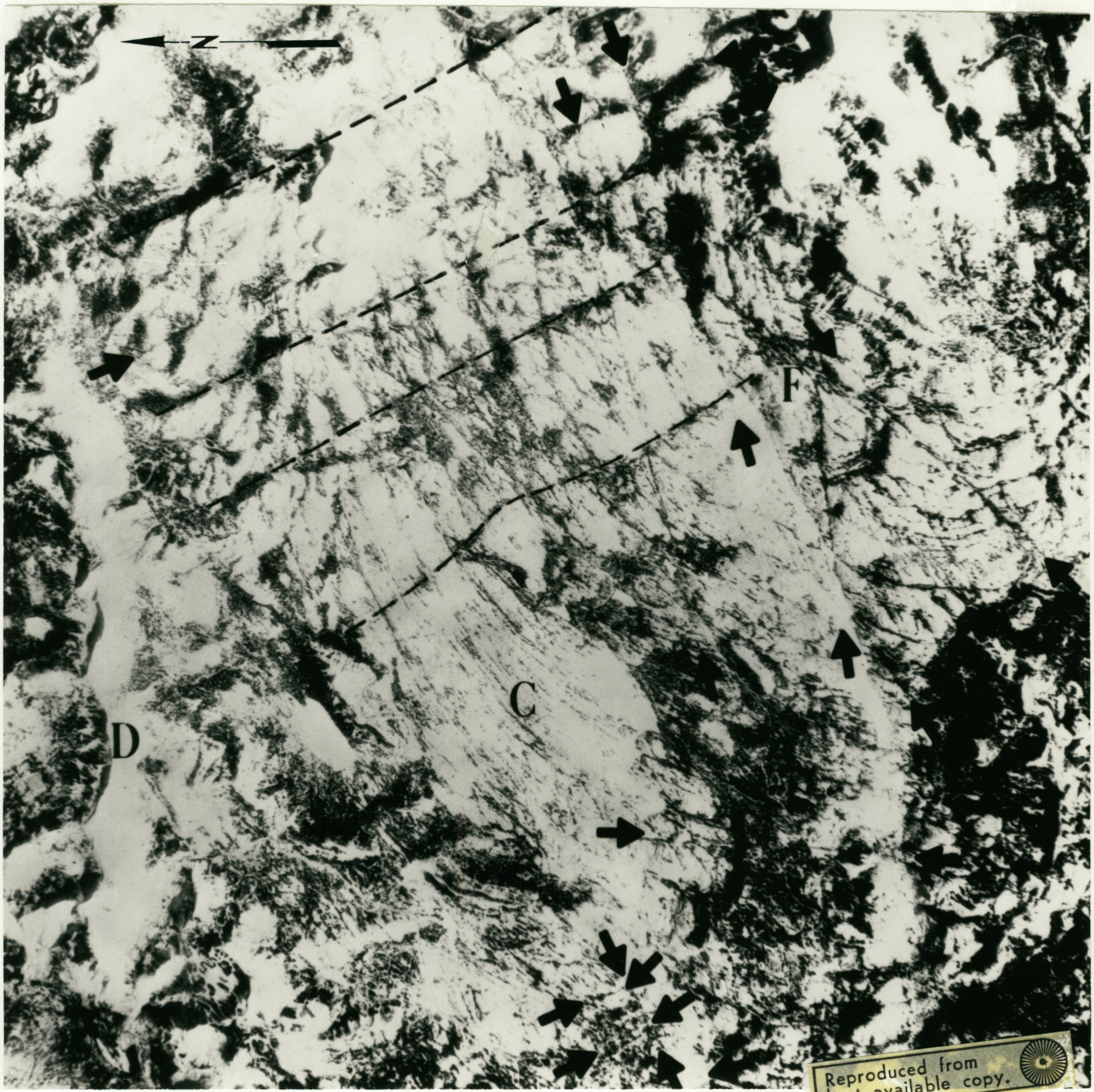

Figure 1: This (580-680nm. band) 70mm photographic enlargement shows a predominantly granitic area south of Lake Tahoe. The photography was acquired on January 31, 1972 by U-2 ERTS simulation aircraft. Snow cover which is extensive over the photograph accentuates crescentic fracturing patterns at (C). Apparent cross-faulting (F) and significant fracture patterns (solid black arrows) can be identified. These fracture patterns are more conspicuous because of the tonal contrasts present between the dark tones of fracture lineations and white tones of surrounding snow-capped outcrop areas. Major geological trends, the origin of which has not been determined, are noted by dashed lines. The fracture lineations which were delineated did not appear on available geological maps of this area. Aeolian snow alignments were detected with magnification; there is little difficulty in distinguishing snow alignments and snow drift banks (D) from fracture lineaments.

Figure 2: The above ERTS-1 image (1077-15011-7) was acquired on 08 October 1972. The imaged area contains eastern Connecticut, Rhode Island and portions of southeastern Massachusetts. During a preliminary analysis, the above major lineaments were detected (arrows). Interpretive emphasis was placed on the detection of geolineaments, although the geologic validity of many of the above lineaments will require more intensive analysis.

EARTH SATELLITE CORPORATION
(EarthSat)

1771 N STREET, N. W., WASHINGTON, D. C. 20036 / (202) 785-1123

November 15, 1972

PROGRESS REPORT SUMMARY

Reporting Period: May 26, 1972 - October 31, 1972

CATEGORY: 8-Interpretation Techniques Development

SUB-CATEGORY: C-General

TITLE: Facilitating the Exploitation of ERTS-Imagery Using Snow Enhancement Techniques - SR #141

PRINCIPAL INVESTIGATOR: Dr. Frank J. Wobber

CO-INVESTIGATOR: Mr. Kenneth R. Martin

SUMMARY:

Pre-launch preparations have focused on the accumulation of complete and comprehensive ground truth information to facilitate more effective analysis of ERTS-1 data. A snow depth reporting network within western Massachusetts and Connecticut has been organized with assisstance from the National Weather Service. Weekly snow depth data will serve to define the effect of varying depths of snow cover on the detectability of fractures.

Analysis of all available (Gemini, Apollo, Nimbus, NASA aircraft) small-scale snow-covered imagery has been conducted to develop and refine snow enhancement techniques. A detailed photographic interpretation of ERTS-simulation imagery covering the Feather River/ Lake Tahoe area was completed; the 580-680nm. band was determined to be the optimum band for fracture detection.

ERTS-1 MSS bands 5 and 7 are best suited for detailed fracture mapping. The two bands should provide more complete fracture detail when utilized in combination.

Analysis of early ERTS-1 data along with U-2 ERTS simulation imagery indicates that snow enhancement is a viable technique for geological fracture mapping. A wealth of fracture detail on snow-free terrain was noted during preliminary analysis of ERTS-1 images 1077-15005-6 & 7, 1077-15011-5 & 7, and 1079-15124-5 & 7. A direct comparison of data yield on snow-free versus snow-covered terrain will be conducted within these areas following receipt of snow-covered ERTS-1 imagery.

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

NDPF USE ONLY
D
N
ID

DATE November 1, 1972

PRINCIPAL INVESTIGATOR Frank J. Wobber

GSFC

ORGANIZATION EarthSat

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS* Lake	River	Ridge	DESCRIPTORS
1045-15243-4 01	X	X	X	Anticlinal Mtn.
1045-15243-5 01	X	X	X	Anticlinal Valley
1045-15243-6 01	X	X	X	Alluvial Terrace
1045-15243-7 01	X	X	X	Anticline
				Fault
				Dendritic Drainage
				Fold
				Gap
				Lineament
				Mine
				Meander
				Piedmont
				Rectangular Drain
				Synclinal Valley
				Syncline
1062-15190-4 01	X	X		Alluvial Plain
1062-15190-5 01	X	X		Alluvial Terrace
1062-15190-6 01	X	X		Bay
1062-15190-7 01	X	X		Coastal Plain
				Dendritic Drainage
				Fall Line
				Flood Plain
				Lineament
				Piedmont

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

MAIL TO ERTS USER SERVICES
CODE 563
BLDG 23 ROOM E413
NASA GSFC
GREENBELT, MD. 20771
301-982-5406

GSFC 37-2 (7/72)

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

DATE November 1, 1972

PRINCIPAL INVESTIGATOR Frank J. Wobber

GSFC

ORGANIZATION EarthSat

NDPF USE ONLY
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N
ID

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS* Lake	River		DESCRIPTORS
1024-15064-4 01	X	X		Coast Line
1024-15064-5 01	X	X		Coastal Plain
1024-15064-6 01	X	X		Flood Plain
1024-15064-7 01	X	X		Dendritic Drainage
				Lineament
				Basin
				Piedmont
				Meander
				Bedding
1045-15245-4 01	X	X		Alluvial Plain
1045-15245-5 01	X	X		Anticlinal Mtn.
1045-15245-6 01	X	X		Anticlinal Valley
1045-15245-7 01	X	X		Anticline
				Basin
				Dendritic Drainage
				Fault
				Flood Plain
				Fold
				Gap
				Geofracture
				Lineament
				Meander
				Piedmont
				Rectangular Drainage
				Ridge
				Syncline
				Synclinal Valley
				Thrust Fault
				Quarry

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ID

DATE November 1, 1972

PRINCIPAL INVESTIGATOR Frank J. Wobber

GSFC

ORGANIZATION EarthSat

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS* Lake	River		DESCRIPTORS
1005-15005-4 01 1005-15005-6 01 1005-15005-7 01	X X X	X X X		Alluvial Plain Barrier Bar Basin Coast Line Coastal Plain Dendritic Drainage Geofracture Island Lineament Meander Piedmont River Fault
1023-15005-4 01 1023-15005-5 01 1023-15005-6 01 1023-15005-7 01	X X X X	X X X X		Basin Coast Line Lineament Piedmont River
1023-15003-4 01 1023-15003-5 01 1023-15003-6 01 1023-15003-7 01	X X X X	X X X X		Coastal Plain Coast Line Dendritic Drainage Lake Lineament Meander Piedmont River

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

MAIL TO ERTS USER SERVICES
CODE 563
BLDG 23 ROOM E413
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GREENBELT, MD. 20771
301-982-5406

GSFC 37-2 (7/72)

APPENDICES

APPENDIX A

TASK STATUS REPORT

TASK		STATUS	COMMENTS
PHASE I			
1.0	Establish Technical Interface With NDPF	Completed 6/30/72	Meetings held with the scientific monitor: ERTS-simulation U-2 aircraft imagery analyzed.
2.0	Assemble Geological Maps and Snow Cover Data	Completed 10/31/72	Subscription to New England Climatological Data: State geological maps of Massachusetts, Connecticut, Vermont, New Hampshire, and geological quadrangle maps for western Massachusetts purchased and analyzed.
3.0	Select and Establish Snow Points	Underway	A comprehensive net of weather stations has been organized. Physical ground points for light aircraft survey may not be required.
4.0	Base Map & Underflight Preparation	Completed 10/31/72	Base map scale determined: Other New England investigators contacted.
5.0	Lineament Map Preparation	Completed 8/30/72	Radar imagery of Massachusetts, Connecticut, and Rhode Island was intensively analyzed to prepare geological lineament maps of the test area.
6.0	Snow Cover and Snow Melt Survey	Underway	Survey package designed and has been sent to newspapers in low density snow depth reporting areas.
PHASE II			
1.0	Select & Analyze Snow Free ERTS Imagery	Underway	All ERTS-1 imagery of the test area analyzed upon receipt. Images 1062-15190-5 and 7 of the Maryland test area will be enlarged to a 1:250,000 scale to serve as a photo base map.

TASK	HEADING	STATUS	COMMENTS
2.0	Analyze Snow Covered Imagery	Not Available For Test Area	
3.0	Prepare & Submit A Preliminary Data Analysis Plan	Underway	A preliminary Data Analysis Plan has been drafted and submitted to the technical monitor for his approval.
PHASE III			
1.0	Modify Manual Optical & ADP Enhancement Techniques	Pending Approval of Data Analysis Plan	
2.0	Process ERTS Imagery Through Last Snow-Covered Period	Pending Approval of Data Analysis Plan	
3.0	Prepare Final Report	Underway	Sections of Final Report are being written as the experiment progresses.
4.0	Prepare NDPF User Manual	Awaiting Arrival of ERTS-1 Snow-Covered Imagery	

APPENDIX B

EARTH SATELLITE CORPORATION
(EarthSat)

1771 N STREET, N.W., WASHINGTON, D.C. 20036 / (202) 785-1123

Dear Cooperative Observer:

We at Earth Satellite Corporation (EarthSat) are currently engaged in an experiment in which we believe you can be a valuable aid to us. The experiment is funded by NASA and utilizes imagery from the ERTS satellite which was launched on July 23rd. (See attached press release).

It is important for us to have regular records of the snow depth in the region of western Massachussetts and Connecticut during this coming winter. Unfortunately, there are not enough weather stations which normally report snow depth, i.e., snow on ground, data within this region to afford us an accurate impression. Therefore, we are asking your cooperation in helping us establish a snow depth network.

Your part in this scientific experiment would involve making and reporting snow depth measurements at once-a-week intervals. If convenient,[1/] the measurements should be taken at a few different topographic locations (e.g. hilltop, hillside, etc.). At each location, three or four measurements should be made so that a reliable average can be obtained. The measurements should be taken at the same locations throughout the experiment. Precision accuracy is not required as readings to the nearest inch will meet minimum experiment standards. The measurements may be made on days and at times to best suit your convenience. To make your reporting more convenient, self-addressed postcards will be provided through the National Weather Service. A sample snow depth observation postcard is enclosed.

The starting date for this activity would be about October 15 of this year with an estimated termination date of March 15, 1973. Your participation would be greatly appreciated by us and to reciprocate, EarthSat would be pleased to send each participant an ERTS satellite photographic print of the western Massachusetts or Connecticut region. Your name will also be listed in the principal report of the investigation.

Also enclosed is a reply postcard by which we hope you will inform us of your desire to participate in this ERTS experiment. On the card there is also space for the addresses of any other parties who might accumulate snow depth data. It would be helpful if you would enter your telephone

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1/ We recognize that in many (if not most) cases it would be inconvenient to obtain measurements at more than one or two locations therefore we stress that this should only be done if convenient for the observer.

number so that we might contact you if some unusual situation develops. We promise not to divulge your number to anyone outside our office.

Further information about our company, the experiment, or your part in the experiment will be supplied upon request.

Thank you for your help. We hope to contact some of you personally as our studies in the area proceed.

Sincerely

Frank J. Wobber

Frank J. Wobber
Director
Geosciences and Environmental
Applications
NASA Principal Investigator

FJW:mh
Enclosure

REPLY POSTCARD

I am willing to supply snow depth data for the experiment:

YES__ NO____ for OCT__ NOV___ DEC____ JAN__ FEB__ MAR___
(Check One) (Check all that apply)

If Yes, please give Station Number _____ Station Name ______________

Approximate Geographic Location ______________________________
(e.g., 2 miles west of Amherst on Boston Road)

Address of other parties who may be able to supply snow depth information (other than National Weather Service weather stations):

____

____

PLEASE RETURN THIS CARD EVEN IF YOU DO NOT DESIRE TO PARTICIPATE IN THE EXPERIMENT.

My Telephone Number Is ______________________

EXAMPLE REPORTING POSTCARD

Observer: ______________________ Station Name: ________________

Location: ____
(County) (State)

Station Number	Snow Depth - Inches (average)	Location	Observation Date (Numerical)
8,000	inches on . . .	Hilltop	12/7/72
	" on . . .	Hillside	
	" in . . .	Valley Bottom	
	" on . . .	Plain (level area)	

REMARKS; Snow drifting lightly in valley.

SNOW DEPTH REPORTING POSTCARD

Observer:______________ Station Name:______________

Location:____
(County) (State)

Station Number	Snow Depth - Inches (average)	Location	Observation Date (numerical)
	___inches on...	Hilltop	
	___ " on...	Hillside	
	___ " in...	Valley Bottom	
	___ " on...	Plain (level area)	

Remarks:

NASA AWARDS EARTH ORBITAL

STUDY USING SNOW COVER FOR

ENHANCEMENT OF GEOLOGICAL FEATURES

The National Aeronautics and Space Administration recently announced the award of a study to evaluate snow enhancement techniques for geological study purposes which will utilize ERTS-A satellite data. Dr. Frank J. Wobber of Earth Satellite Corporation, Washington, D.C. is the principal investigator.

It is probable that wintertime imagery provided by ERTS-A may be under-utilized by the scientific community. Aerial survey experience which advances the premise of "no leaves and no snow" for successful geological data acquisition will probably extend to ERTS-A. A successful demonstration that snow cover can enhance the information content of ERTS imagery could increase the utility of ERTS.

Experience gained from orbital photographs suggests that snow cover, and probably the monitoring of progressive snow cover changes (snow melting) using repetitive ERTS-A imagery can increase the utilization of low resolution (small scale) imagery. Techniques to exploit low resolution ERTS products are needed by the image interpretation community, and to insure ERTS wintertime data are fully utilized.

Lithological and structural data have historically been collected during snow-free periods on the assumption that snow cover during progressive stages of melting or accumulation may enhance subtle fracture traces of drainage patterns useful for discriminating lithology. Repetitive ERTS-A imagery provides an opportunity to evaluate geological data obtained during snow-covered versus snow-free periods. The technique can prove especially useful to geologists when it is used for the exploitation of imagery with low spatial resolution. Snow enhancement techniques could also seasonally extend geological studies in northern latitudes and particularly in areas of permanent snow cover.

Conceptual work has been reinforced by recent analysis of Apollo photographs which suggests that snow cover may accentuate subtle fractures and textural variations suggestive of lithological change. Manual fracture analysis has already been conducted more speedily (and accurately) in snow-covered rather than snow-free terrain.

The techniques can specifically provide an increased facility for detecting and analyzing subtle fracture systems and lithological changes as reflected by fracture or drainage density. Snow enhancement, which provides data applicable to the location of previously unidentified (subtle) fractures as well as a better understanding of fracture orientation, can have immediate applications which vary from minerals and petroleum exploration to underground excavation for high speed transportation systems.

The techniques developed can not only enhance the utilization of relatively low resolution data collected by ERTS-A and future terrestrially-oriented satellite systems, but also insure further utilization of wintertime ERTS imagery.

APPENDIX C

FACILITATING THE EXPLOITATION OF ERTS-IMAGERY USING SNOW ENHANCEMENT TECHNIQUES

SR #141

FINAL REPORT WORKING OUTLINE

Prepared By

Frank J. Wobber
and
Kenneth R. Martin

October 31, 1972

EARTH SATELLITE CORPORATION
GEOSCIENCES AND ENVIRONMENTAL APPLICATIONS DIVISION
1771 N Street, N.W. Washington, D.C. 20036
(202) 785-1123

I. INTRODUCTION

A. Justification and Need for Experiment

- Anticipated Value to Small Scale Image Analysis
- Anticipated Value to Geofracture Studies

B. Statement of Broad Experiment Objectives

- Permit More Full Utilization of ERTS Imagery

II. BACKGROUND

A. Concept of Snow Enhancement

- Discussion as to Why Enhancement Occurs

B. Past Observation of Snow Enhanced Phenomena

C. Pre-ERTS Investigative Efforts

1. Analyses of Rocket and Satellite Photography (Nimbus, Gemini, Apollo, Mercury, Viking)

2. Feather River Analysis -- ERTS Simulation U-2

III. EXPERIMENT DESIGN

A. Discussion of Specific Experiment Objectives

B. Selection of Test Areas

1. ERTS Interest Region -- Southern New England

(a) geological interest and diversity

(b) extended periods of snowfall of various depths

(c) proximity to working base

(d) active USGS mapping program

2. Primary Test Area -- Western Massachusetts

   (a) geological interest and diversity

   - glacial cover
   - exposed bedrock
   - low mountainous terrain
   - adjacent rugged terrain
   - presence of non-structural (glacial) linears

   (b) availability of geologic data (such as)

   - radar imagery
   - high altitude (aircraft imagery)
   - aeromagnetic maps
   - active USGS mapping program
   - structural geological maps
   - published articles/unpublished maps

   (c) availability of snow depth data, i.e., relative abundance of ground truth stations

3. Secondary Test Areas

   (a) New Hampshire, Vermont, Connecticut

   - high interest sites designated as experiment progresses

   (b) Maryland

   - convenient observations of progressive snow melting effects
   - immediate access to field checks of snow depth effects on subdued drainage, geomorphology and structure (fracture)

C. Acquisition of Ground Truth Data

1. Snow Information Network

(a) data gathering methods considered

- ground equipment (e.g. snow pillow recorders)
- reference (snow) points (light aircraft)
- NWS weather stations
- postcard return (general public-newspaper contacts)
- frequent field vists

(b) principal data contributors in experiment

- NWS co-operative weather observers
- reference (snow) points
- public postcard return (newspaper contacts)
- NWS weather stations
- Massachusetts Department of Water Resources

(c) frequency of data acquisition

- weekly (co-operative observers).
- eighteen day (ERTS) cycle -- aerial observations (hand-held photography of snow points)
- public postcard return

(d) sources of ground truth errors

- interpolation (over extension of)
- solar aspect (solar illumination)
- rapid changes of snow cover

(e) magnitude and importance of errors

2. Geological Information Base

(a) synthesis of existing geologic information

- geological quadrangles
- state geological maps
- published reports

(b) extension of existing information capabilities

- field trips (to observe selected areas)
- low altitude flights (near vertical photography of high interest areas)
- low altitude oblique flights (to observe and photograph suspect lineaments from low altitudes and enhanced viewing perspective)
- preparation of geolineament maps from existing radar mosaics

D. <u>Acquisition of Supporting (NASA) Aircraft Data</u>

1. <u>General Area Surveys</u>

2. <u>Underflight During ERTS-1 Overpass</u>

IV. <u>DESCRIPTION OF ANALYTICAL PROCEDURES</u>

A. <u>Manual</u>

1. Vertical Viewing

B. <u>Enhanced Manual</u>

1. Oblique Viewing
2. Film Sandwiching

C. <u>Automated Enhancement</u>

1. Density Slicing (Digicol)
2. Additive Color (Addcol)
3. Computer Enhancement of Digital Tapes
4. Automated Detection of Lineaments

D. Integration of Ground Truth Data

1. Validation of Interpreted Lineaments

- topographical maps
- geolineament radar map
- geological maps
- direct field observation
- supplementary high altitude remote sensing records

E. Integration of Supplementary Aircraft Coverage

1. Vertical Photographic Coverage

- existing 1:76,000 snow free photography
- ERTS-1 underflight during snow cover

2. Oblique Photographic Coverage (as needed)

F. Evaluation of Analytical Procedures

1. Manual
2. Enhanced Manual
3. Automated Enhancement
4. Supplementary Aircraft Coverage

(a) routine coverage

(b) special effects (oblique)

V. EXPERIMENT RESULTS

A. Analysis of Sensor Bands

1. General Capabilities and Limitations

(a) RBV Bands (individual evaluation)

(b) MSS Bands (individual evaluation)

B. Optimal Climatic Conditions (for geological snow enhancement)

1. Discussion of Importance of Snow Depth

2. Discussion of Importance of Differential Melting

3. Other Variables

C. Geological Utility of Snow Enhancement

1. Fracture Analysis

(a) near surface lineament detection

- detection of known lineaments
- detection of previously unrecorded lineaments
- comparison of detection capability for snow vs. non-snow areas
- discussion of why near surface lineaments are enhanced (permeability differential)

(b) fracture trace detection

- comparison of snow vs. non-snow areas
- discussion why fracture traces are enhanced

(c) lithology favoring maximum fracture/fracture trace enhancement

2. Drainage Pattern Analysis (lithological differentiation)

3. Regional Structural Analysis

4. Stratigraphic Analysis

(a) snow enhancement as an aid in differentiation of strata

(b) discussion of differing snow retention capacities of strata

- permeability differential
- emissivity differential
- vegetative cover differences

V. <u>EXPERIMENT RESULTS</u> (cont.)

(c) potential for tracing (and mapping) key strata in snow-covered areas

D. <u>Observations of Related Snow Enhancement Capabilities</u>

1. Climatological (determination of wind direction)

2. Land Use (surficial cover mapping)

(a) enhancement of cultural features

- thermal pipelines
- street patterns.

(b) enhancement of vegetative cover differences

3. Hydrological (ice formation, breakup and melt)

(a) detection of ground water outfalls

VI. <u>SUMMARY AND CONCLUSIONS</u>

A. <u>Discussion of Merits of Snow Enhancement as a Photogeologic Tool</u>

1. Utility for Aerial Photographic Studies

2. Utility for Small Scale (low resolution) Imagery

B. <u>Synopsis of the Most Important Experiment Results</u>

1. Detection of Previously Unmapped Fractures

2. Extension of Usability of ERTS Snow-Covered Imagery

C. <u>Discussion on Feasibility for Extension of Techniques into Permanently Snow-Covered Areas</u>

1. Comparison of New England Areas (in Winter) with Areas of Permanent Snow Cover

2. Extrapolation of Snow Thickness (maximum depth) experience from New England to Permanently Snow-Covered Regions

3. Application of Ground Truth Data Gathering Techniques Designed for this Experiment (principally snow points) to Permanently Snow-Covered Areas

    (a) conditions where aerial data acquisition would realize maximum usefulness

    - environmentally hostile or inaccessible terrains

    - terrains in which ground truth stations are not widespread or totally non-existent

D. <u>Closing Statements on Recommendations for Continuing Snow Enhancement Research</u>

<u>REFERENCES</u>

APPENDIX D

PROGRAM SECTION 9 (EXPLORATION GEOPHYSICS) *

INTERNATIONAL GEOLOGICAL CONGRESS

TUESDAY, AUGUST 22, 1972

GEOLOGY OF THE EARTH FROM SATELLITE OBSERVATIONS

Session Chairmen: A. G. Darnley, Geological Survey of Canada, Ottawa, Ontario, Canada

L. N. Chaturvedi, Department of Civil Engineering, Indian Institute of Technology, New Delhi, 29, India.

TIME	
8.30 - 9.00	ERTS IMAGERY OF CANADIAN TERRAIN MORLEY, L. W. Canadian Centre for Remote Sensing, Department of Energy, Mines and Resources, Ottawa, Ontario, Canada.
9.00 - 9.25	GEOLOGICAL EXPLOITATION OF SATELLITE IMAGERY USING SNOW ENHANCEMENT TECHNIQUES WOBBER, F. J. Earth Satellite Corporation, 1771 N Street N.W. Washington, D. C. 20036, U. S. A.
9.25 - 9.50	GEOLOGICAL MAPPING OF NORTHERN AUSTRALIA FROM SATELLITE PHOTOGRAPHS STELLER, D. D. Space Division, North American Rockwell Corporation, Downey, California 90241, U. S. A.
9.50 - 10.15	THE STRUCTURAL SIGNIFICANCE OF MULTISPECTRAL APOLLO 9 PHOTOGRAPHS TO APPALACHIAN GEOTECTONICS DRAHOVZAL, J. A. AND NEATHERY, T. L. Geological Survey of Alabama, P. O. Drawer O, University of Alabama, University, Alabama 35487, U. S. A.
10.15 - 10.40	MAGNETIC ANOMALIES FROM A SATELLITE MAGNETOMETER Zeitz, Isidore U. S. Geological Survey, 8300 Colesville Road, Silver Spring, Maryland, U. S. A.
10.40 - 11.00	DISCUSSION

*All Section 9 sessions will be held in the Saguenay and St. Maurice Rooms, Queen Elizabeth Hotel, 900 Dorchester Blvd., West, Montreal.