LARS Information Note 021171

Description and Results of the LARS/GE Data Compression Study

by David Landgrebe

The purpose of this Information Note is to report the results of an evaluation of the sensitivity of a maximum liklihood pattern classification system to several data compression schemes in the face of noise. The compression schemes were suggested and implemented by the General Electric Company under contract to NASA.[1]

At LARS, a data system parameter study has been underway for some time. The purpose of this study is to determine the sensitivity of system performance to such data system parameters as spectral and spatial resolution, signal-to-noise ratio, registration precision, data compression and others.

As a result of these joint interests by LARS and GE, a cooperative study into the effects of the G. E. data compression schemes was initiated. The steps followed in this study were as follows:

1. Suitable flightlines were jointly selected for the study. It was decided initially to pick flightlines which were typical of agricultural scenes, but which also had been well studied in order that anomalies would be understood. The flightlines selected are indicated in Table 1; and all are data collected by the Michigan multispectral scanner system over Purdue flightlines. This data was written onto tape by LARS and transmitted to G.E.

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[1] Multispectral Scanner Data Redundancy Study, NASA contract NAS5-21151, Project Manager: Mr. Ronald Kern, Room U2450, General Electric Company, Valley Forge Space Center, P. O. Box 8555, Philadelphia, Pa. 19101
Technical Monitor: Mr. Joseph Silverman, NASA Goddard Space Flight Center, Greenbelt, Maryland

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Flight Line	Run Number	No. of Scan Lines
C1 June 66	66000600	951
C2 June 66	66000800	887
C1 July 66	66007700	1111
C2 July 66	66007900	1144

Table 1. Flight lines of data selected for test

2. It was originally intended that G. E. would combine appropriate spectral bands of the 12-channel data so as to simulate the 4-bands of the ERTS scanner. It was later decided, however, that four of the scanner bands were already sufficiently near to the four ERTS channels so as not to require the use of a combination of scanner bands. Table 2 shows a comparison of the ERTS channels with the airborne scanner channels used. The second step thus became the processing of these four bands of data through data compression algorithms and appropriately re-expanding the data as will be described below. This was done by G. E.

ERTS Channels - μm	Airborne Scanner Channel used - μm	Channel Number
.50-.60	.52-.55	6
.60-.70	.62-.66	9
.70-.80	.72-.80	11
.80-1.1	.80-1.0	12

Table 2. Spectral band comparison

3. The re-expanded data was returned to LARS and data classifications were run using the LARSYSAA data classification system. A quantitative evaluation of these classifications using test fields compared against a like classification of data not having been compressed and re-expanded was used to evaluate the effect of the compression schemes on the classification accuracy.

It was later decided to test the compression schemes and classification accuracy in the face of additive noise simulating a decreased signal-to-noise ratio due to detector noise. The details of the noise generation and addition together with a description of the compression algorithms tested will be given next.

Description of Compression Algorithms

Four different compression algorithms were tested in the manner described above. Each of the four was also tested with two different noise levels. The descriptions of these algorithms which are provided here are taken from private correspondence between LARS and G. E. The descriptions are as follows:

Compression Algorithm Number 1 - Sampled Element - Unscaled

The technique here is simply to transmit only every fourth sample as follows:

In each scan line transmit sample 1 of channel 1, sample 2 of channel 2, sample 3 of channel 3, sample 4 of channel 4, sample 5 channel 1, sample 6 channel 2 etc. The reconstruction consists of replacing the missing pixels (samples) with pixels of the same intensity as the last sample transmitted in that particular band. In this case, since only 1/4 of the data is transmitted the resultant bandwidth reduction is 4 to 1.

Compression Algorithm Number 2 - Sampled Element - Scaled

In this scheme, alternate picture elements are sampled in the same fashion as in compression algorithm number 1; thus, only 1/4 of the picture elements have been retained at this point. However, in this case, all four channels are summed prior to sampling to create a luminous channel called the Z or intensity channel. All samples of this channel are also transmitted to the ground; thus, a full bandwidth channel is used for the luminous channel, whereas each of the four sample channels requires a 1/4 bandwidth channel. Therefore, the net amount of data transmitted is equivalent to two full channels, and the net bandwidth compression is 2 to 1.

The following is a description of the ground reconstruction used for this algorithm:

Consider band 1. If this band is sampled in the first, fifth, ninth, etc. pixel, these same pixels will be used directly to fill those pixels in the reconstruction. However, the reconstructed values of pixels 2, 3, and 4 are the values sampled in pixel 1 times the ratio of intensity that existed in pixel 2 divided by that in pixel 1, pixel 3 divided by pixel 1, and pixel 4 divided by pixel 1. Likewise, the intensities used on reconstruction of pixels 6, and 8 is that sampled in pixel 5 scaled by the intensity difference between 5 and 6, 7 and 8.

Compression Algorithm Number 3 - Low passed filtered with mixed highs

In this case, the data is low passed filtered digitally in each band using a filter time constant equivalent to one pixel in width. The low pass filtered version of the data is then subtracted from the original data in each band to obtain a high pass filtered version of that band. Next, in each pixel, the four high pass filtered versions are added and divided by four. This gives a new

final high pass filtered version, which may be considered a high pass filtered version of the luminuous or intensity channel. This final high pass filtered data is then sent to the ground. It requires one full bandwidth.

Simultaneously, the low pass filtered data is sampled in the manner of the compression algorithm number 1; that is, each band is sampled once every four elements. These data are also sent to the ground. The total compression thus achieved by this algorithm is a factor of two. The reconstruction in each band depends upon the last sampled pixel in that band and on the high pass filtered data sent to the ground for the particular pixel in question.

Compression Algorithm Number 4 - Three-band Compression of Gray Scale and Resolution. In this scheme one band would be sent to the ground uncompressed and the other three bands would be selectively compressed in gray scale and in resolution (by not sampling each pixel). The details of this algorithm are described in a memo supplied to LARS by G.E. and attached to this information note as Appendix A.

As previously mentioned these algorithms were to be tested in the face of additive white Gaussian noise. Two different noise levels were used. The noise levels were selected by G. E. in an attempt to simulate noise levels which might be present in "a bright scene" and "a dim scene". The noise levels added to each spectral band in the two cases are given in Table 3. The noise level in this table is specified in terms of the number of bins out of 256 per one standard deviation. The mean value of the noise was adjusted to zero. The noise was to be white Gaussian and uncorrelated from spectral band to spectral band; however, through an error in programming the generation of Noise Level 2, this noise is not uncorrelated between spectral bands.

Channel - μm	1 σ for Noise level 1	1 σ for Noise level 2
.52-.58	3.2	10.4
.62-.66	3.9	12.8
.72-.80	7.1	23.3
.80-1.0	4.1	13.3

Table 3. Standard deviations of noise used in test

GE DATA COMPRESSION STUDY

SERIAL NUMBER-------- 72200560I CLASSIFIED- SEPT 22,1970

SAVED TRAINING FIELDS

	RUN NUMBER	FIELD DESIG.	FIRST LINE	LAST LINE	LINE INT.	FIRST COLUMN	LAST COLUMN	COLUMN INT.	FIELD TYPE	OTHER INFORMATION	CLASSIFY CLASS	DISPLAY CLASS
1	66000600	25-6	65	91	2	89	89	2	3	SOYBEANS1	SOYBEANS	SOYBEANS
2	66000600	11-13	237	251	2	151	167	2	3	SOYBEANS2	SOYBEANS	SOYBEANS
3	66000600	36-7	107	127	2	59	81	2	3	SOYBEANS3	SOYBEANS	SOYBEANS
4	66000600	7-21	273	287	2	135	179	2	3	SOYBEANS4	SOYBEANS	SOYBEANS
5	66000600	36-4	167	177	2	55	77	2	1	CORN1	CORN	CORN
6	66000600	36-9	267	283	2	65	81	2	1	CORN2	CORN	CORN
7	66000600	36-8	119	141	2	21	51	2	1	CORN3	CORN	CORN
8	66000600	12-9	603	625	2	15	55	2	1	CORN4	CORN	CORN
9	66000600	6-2	165	175	2	165	185	2	3	OATS1	OATS	OATS
10	66000600	1-11	421	455	2	43	63	2	3	OATS2	OATS	OATS
11	66000600	7-1	581	599	2	135	161	2	3	OATS3	OATS	OATS
12	66000600	31-12	295	361	2	119	175	2	4	WHEAT1	WHEAT I	WHEAT
13	66000600	6-14	471	495	2	177	201	2	4	WHEAT2	WHEAT I	WHEAT
14	66000600	7-2	807	865	2	203	211	2	4	WHEAT3	WHEAT I	WHEAT
15	66000600	6-10	619	667	2	159	180	2	6	RED CL3	RED CLVR	RED CLVR
16	66000600	1-1	539	563	2	175	195	2	6	RED CL2	RED CLVR	RED CLVR
17	66000600		589	619	2	69	95	2	6	RED CL1	RED CLVR	RED CLVR
18	66000600	7-20	731	737	2	129	177	2	6	ALFALFA1	ALFALFA	ALFALFA
19	66000600	7-24	749	755	2	131	171	1	6	ALFALFA2	ALFALFA	ALFALFA
20	66000600	7-22	809	817	1	155	183	1	6	ALFALFA3	ALFALFA	ALFALFA
21	66000600	6-8	543	569	1	127	155	2	7	RYE1	RYE	RYE
22	66000600	36-1	97	115	1	49	85	1	5	UR GU -	BR SOIL	BR SOIL
23	66000600	12-10	655	695	2	17	41	2	4	WHEAT4	WHEAT II	WHEAT

Table 4. List of Training Samples

GE LARS COMPRESSION STUDY

SERIAL NUMBER------- 77705401 CLASSIFIED- SEPT 27,1970

SAVED TEST FIELDS

	RUN NUMBER	FIELD DESIG.	FIRST LINE	LAST LINE	LINE INT.	FIRST COLUMN	LAST COLUMN	COLUMN INT.	FIELD TYPE	OTHER INFORMATION	CLASSIFY CLASS	DISPLAY CLASS
1	66000600	29-6	57	89	2	47	101	2		SOYBEANS	SOYBEANS	SOYBEANS
2	66000600	30-6	61	79	2	115	169	2		SOYBN COVERS W	SOYBEANS	SOYBEANS
3	66000600	31-1	93	101	1	116	168	1		SOYBN COVERS W	SOYBEANS	SOYBEANS
4	66000600	36-2	123	133	2	43	101	2		SOYBEANS	SOYBEANS	SOYBEANS
5	66000600	36-2	133	149	2	43	83	1		SOYBEANS	SOYBEANS	SOYBEANS
6	66000600	31-13	217	273	2	109	201	2		SOYBEANS	SOYBEANS	SOYBEANS
7	66000600	12-3	705	797	2	69	111	2		SOYBN E PRE PR	SOYBEANS	SOYBEANS
8	66000600	36-7	291	341	2	45	97	2		SOYBN VOLUNTR	SOYBEANS	SOYBEANS
9	66000600	6-9	489	519	2	115	161	2		SOYBEANS	SOYBEANS	SOYBEANS
10	66000600	7-27	643	661	2	125	197	2		SOYBEANS	SOYBEANS	SOYBEANS
11	66000600	12-7	647	659	2	51	87	2		SOYBEANS	SOYBEANS	SOYBEANS
12	66000600	12-6	667	675	2	93	111	2		SOYBEANS	SOYBEANS	SOYBEANS
13	66000600	12-5	705	747	2	51	85	2		SOYBN W. PRE P	SOYBEANS	SOYBEANS
14	66000600	7-23	759	785	2	121	197	2		SOYBN PLT CIRC	SOYBEANS	SOYBEANS
15	66000600	36-9	157	187	2	17	101	2		CORN	CORN	CORN
16	66000600	36-8	189	215	2	17	79	2		CORN	CORN	CORN
17	66000600	36-10	221	255	2	19	55	2		CORN	CORN	CORN
18	66000600	36-9	261	287	2	19	65	1		CORN	CORN	CORN
19	66000600	36-8	167	169	2	19	35	2		CORN	CORN	CORN
20	66000600	6-11	401	421	2	111	199	2		CORN	CORN	CORN
21	66000600	12-9	589	643	2	1	43	2		CORN DIFF VARI	CORN	CORN
22	66000600	31-11	927	939	2	109	197	2		OATS	OATS	OATS
23	66000600	6-7	365	377	2	131	183	2		OATS DITCH W L	OATS	OATS
24	66000600	1-11	413	467	2	49	91	2		OATS	OATS	OATS
25	66000600	7-1	561	569	2	121	193	2		OATS	OATS	OATS
26	66000600	31-12	285	317	2	109	199	2		WHEAT	WHEAT II	WHEAT
27	66000600	6-1	147	151	2	107	205	2		WHEAT	WHEAT II	WHEAT
28	66000600	6-1	185	193	2	109	203	2		WHEAT	WHEAT II	WHEAT
29	66000600	6-14	459	509	2	107	211	2		WHT 2 VARIETIE	WHEAT II	WHEAT
30	66000600	7-2	581	589	2	203	211	2		WHEAT	WHEAT II	WHEAT
31	66000600	12-10	649	699	2	1	51	1		WHEAT 2 VAR LO	WHEAT II	WHEAT
32	66000600	31-23	129	133	2	113	199	2		RD CL DIVRT SU	RED CLVR	RED CLVR
33	66000600	1-1	397	399	2	11	95	1		RED CL HAY	RED CLVR	RED CLVR
34	66000600	6-10	933	953	2	111	197	2		RED CL HAY	RED CLVR	RED CLVR
35	66000600	6-7	521	561	2	173	215	1		RED CL PASTURE	RED CLVR	RED CLVR
36	66000600	1-6	559	581	2	59	107	1		RED CL PASTURE	RED CLVR	RED CLVR
37	66000600	12-8	589	633	2	59	109	2		RED CL PASTURE	RED CLVR	RED CLVR
38	66000600	7-29	613	619	2	121	183	2		RD CL DIVERTED	RED CLVR	RED CLVR
39	66000600	7-28	629	637	2	123	191	2		RED CL HAY	RED CLVR	RED CLVR
40	66000600		675	695	2	127	195	2		RED CL	RED CLVR	RED CLVR
41	66000600	7-26	729	737	2	121	193	2		ALFALFA HAY	ALFALFA	ALFALFA
42	66000600	7-24	745	757	2	121	195	2		ALFALFA HAY	ALFALFA	ALFALFA
43	66000600	7-22	781	815	2	121	195	2		ALFA. HAY GRAS	ALFALFA	ALFALFA
44	66000600	6-6	525	577	2	119	163	2		RYE	RYE	RYE
45	66000600	36-3	131	149	2	87	101	2		BARE SOIL	BR SOIL	BR SOIL
46	66000600	36-1	95	117	2	99	99	2		BARE SOIL	BR SOIL	BR SOIL

Table 5. List of Test Samples

Details of Classification Accuracy Tests and Conclusions

Data of flightline C1 June '66 (Run number 66000600) only was used for test due to time limitations. This flightline has been used at LARS for a number of studies and is therefore ideal for this purpose.[1,2] Training samples and test samples for this flightline had previously been selected. The training samples and test samples used are given in Table 4 and 5, respectively. A reference classification was carried out on this flightline using the preferred set of spectral bands as selected by the $SELECT feature selection algorithm.[3] The preferred set of bands turned out to be channels 1, 6, 10, and 12 (.40-.44, .52-.55, .66-.72, and .80-1.00 μm respectively). A printout of this classification is shown as Figure 1. The test class performance for this classification is shown in Table 6. This same list of training samples and test samples was used for each classification in the study.[4]

Table 7 shows the list of runs received from G. E. The results of the classification of these runs in terms of test class performance are given in detail in Appendix B and summarized in Table 8. This table shows the overall classification accuracy for each compression algorithm and noise situation. In the case of no noise there appears to be a slight preference for compression algorithm number 3. This preference continues in the Noise Level 1 trials.

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[1] "Remote Multispectral Sensing in Agriculture" 1968 Report of the Laboratory for Agricultural Remote Sensing, Vol. 3. Purdue University Agricultural Experiment Station, Research Bulletin No. 844, Lafayette, Indiana.

[2] K. S. Fu, D. A. Landgrebe, and T. L. Phillips, "Information Processing of Remotely Sensed Agricultural Data." Proceedings of the IEEE 57:4, pp. 639-653.

[3] "Remote Multispectral Sensing in Agriculture." 1970. Report of the Laboratory for Agricultural Remote Sensing, Vol. 4. Purdue University Agricultural Experiment Station, Research Bulletin No. 873, Lafayette, Indiana.

[4] The actual training samples used for classifying a given data set were drawn from that data set, however.

GE DATA COMPRESSION STUDY

SERIAL NUMBER-------- 4Z2005401 CLASSIFIED- SEPT 22,1970

CHANNELS USED

CHANNEL 1	SPECTRAL BAND	0.40 TO 0.44 MICROMETERS	CALIBRATION CODE = 1	CO =	11.00
CHANNEL 6	SPECTRAL BAND	0.52 TO 0.55 MICROMETERS	CALIBRATION CODE = 1	CO =	11.00
CHANNEL 10	SPECTRAL BAND	0.66 TO 0.72 MICROMETERS	CALIBRATION CODE = 1	CO =	11.00
CHANNEL 12	SPECTRAL BAND	0.80 TO 1.00 MICROMETERS	CALIBRATION CODE = 1	CO =	11.00

CLASSES

	CLASS	GROUP	THRES PCT		CLASS	GROUP	THRES PCT
1	SOYBEANS	SOYBEANS	0.5	5	ALFALFA	ALFALFA	0.5
2	CORN	CORN	0.5	7	RYE	RYE	0.5
3	OATS	OATS	0.5	8	BR SOIL	BR SOIL	0.5
4	WHEAT I	WHEAT	0.5	9	WHEAT II	WHEAT	0.5
5	RED CLVR	RED CLVR	0.5				

TEST CLASS PERFORMANCE

	GROUP	NO. OF SAMPS	PCT CORRECT	NUMBER OF SAMPLES CLASSIFIED INTO: WHEAT	SOYBEANS	CORN	OATS	RED CLVR	ALFALFA	RYE	BR SOIL	THRESHOLD
1	WHEAT	2891	97.6	2578	0	0	17	0	0	40	0	0
2	SOYBEANS	7171	90.9	10	6481	210	114	2	3	16	12	421
3	CORN	2775	90.9	1	127	2509	11	77	4	0	0	26
4	OATS	1556	87.0	30	21	8	1355	114	19	10	0	1
5	RED CLVR	3230	93.8	3	18	40	151	2706	290	0	0	20
6	ALFALFA	912	88.6	0	3	0	55	54	790	0	0	3
7	RYE	623	79.8	25	0	0	7	0	1	589	0	0
8	BR SOIL	332	98.8	0	1	1	0	0	6	0	328	1
	TOTAL	19296		2647	6651	2673	1732	2956	1168	657	340	484

OVERALL PERFORMANCE 17130/ 19296 = 90.1

AVERAGE PERFORMANCE BY CLASS 729.37/ 81 = 91.

Table 6. Test Sample Performance for Preferred Channels

Run Number	Tape Number	Description
66000620	907	Reference Data - No Noise
66000621	909	Reference Data - Noise Level 1
66000622	910	Reference Data - Noise Level 2
66000623	907	Sampled Element - Unscaled - No Noise
66000624	909	Sampled Element - Unscaled - Noise Level 1
66000625	910	Sampled Element - Unscaled - Noise Level 2
66000626	908	Sampled Element - Scaled - No Noise
66000627	909	Sampled Element - Scaled - Noise Level 1
66000628	910	Sampled Element - Scaled - Noise Level 2
66000629	908	Low-Pass Filtered with Mixed Highs - No Noise
66000630	909	Low-Pass Filtered with Mixed Highs - Noise Level 1
66000631	910	Low-Pass Filtered with Mixed Highs - Noise Level 2
66000632	908	Intensity Channel
66000635	911	3 Band Compress. of Gray Scale & Resolution - No Noise
66000636	911	3 Band Compress. of Gray Scale & Resolution - Noise Level 1
66000637	911	3 Band Compress. of Gray Scale & Resolution - Noise Level 2

Table 7. List of Runs Received from General Electric

Due to the previously described error resulting in correlation between channels in the Noise Level 2 case, it is inappropriate to draw conclusions in this situation.

The slight preference for Compression Algorithm Number 3 tends to be observed in each class as well as the overall results. Tables 9 and 10 show the best class

performance for two individual classes. Table 9 gives the performance for soybeans, a relatively difficult class to identify. Table 10 shows the same results for the class wheat, a much simpler classification task. It is interesting to note that with Noise Level 1, several of the results from the compressed data are higher than the accuracies obtained on the uncompressed reference data.

Compression Algorithm	Data Description	Overall Test Sample Classification Accuracy in Per Cent: No Noise	Noise Level 1	Noise Level 2	Compression Ratio
	Reference Data (ERTS-Simulated Channels)	79.7	63.6	78.1	--
1	Sampled Element - Unscaled	76.5	62.8	31.8	4
2	Sampled Element - Scaled	76.5	64.5	51.4	2
3	Low Pass Filtered with Mixed Highs	78.5	68.8	43.8	2
4	Three Band Compression of Gray Scale & Resolution	75.3	61.8	46.2	Variable

Table 8. Overall Performance on Test Samples

Compression Algorithm	Data Description	Overall Test Sample Classification Accuracy in Per Cent: No Noise	Noise Level 1	Noise Level 2	Compression Ratio
	Reference Data (ERTS-Simulated Channels)	71.0	50.2	73.1	--
1	Sampled Element - Unscaled	67.3	48.6	16.7	4
2	Sampled Element - Scaled	69.7	53.9	48.8	2
3	Low Pass Filtered with Mixed Highs	70.7	56.5	31.7	2
4	Three Band Compression of Gray Scale & Resolution	66.2	50.1	40.9	Variable

Table 9. Test Class Performance for Soybeans

Compression Algorithm	Data Description	Overall Test Sample Classification Accuracy in Per Cent: No Noise	Noise Level 1	Noise Level 2	Compression Ratio
	Reference Data (ERTS-Simulated Channels)	97.8	88.7	95.3	
1	Sampled Element - Unscaled	96.0	86.2	48.0	
2	Sampled Element - Scaled	96.5	85.2	41.9	
3	Low Pass Filtered with Mixed Highs	96.6	91.5	59.4	
4	Three Band Compression of Gray Scale & Resolution	96.5	80.8	93.7	

Table 10. Test Class Performance for Wheat

While the differences in accuracies indicated in these three tables is, in general, not great as a function of the compression algorithm used, the preference of the classifier for Classification Algorithm Number 3 does seem to be fairly consistent throughout the results. Care must be used, however, in the extrapolation of these results to other situations. There are several reasons for this.

First, the flightline selected for tests was chosen because of the variety of agricultural classes present in this relatively small area. However, it must be kept in mind that the area covered by this flightline (approximately 4 sq. miles) is relatively very small. Further, it does not contain classes typical of other times of the growing season nor of many of the important non-agricultural classes of data.

Second, as a procedural matter test fields are selected from within the agricultural field in such a way as to guarantee that the boundaries of the agricultural field are not included. Since the algorithms themselves are in the main attempting to utilize spatial redundancy to achieve compression, the algorithms may be expected to cause greater degradation of the data in the vicinity of agricultural field boundaries. Thus, one might reasonably expect greater overall degradation than is indicated by these accuracy figures.

Two additional points can be made as a result of the availability of these results. These two points are somewhat tangential to the matter of data compression but are, nevertheless, of considerable interest to the design of future space and aircraft systems. They are as follows:

1. The error in generating the random noise data for noise level 2 does provide an opportunity to illustrate the manner in which correlation between channels affects classification accuracy. Figure 2 shows a printout of channel 12 of the reference data for the No Noise, Noise Level 1, and Noise Level 2 cases. Recall from Table 8 that the accuracies in classification were 79.7, 63.6 and 78.1 respectively. First, it is clear from these results that one cannot predict from a casual glance at imagery or a casual knowledge of the data signal-to-noise ratio, what accuracy will be achievable by machine-processing algorithms capable of taking correlation between channels into account. Second these results illustrate the fact that when degrading effects occur in the data system, the type of degradation is as important as its size.

The reason the very noisy data was more accurately classified than the Noise Level 1 data was that the noise added was highly correlated between channels. Visualize the data in four-dimensional space; it is known that data of this type generally lies along lines which are somewhat radial to the origin. Thus, adding

noise which is highly correlated between channels lengthens the distribution of data along these radial lines, but does not materially contribute to increased overlap of data from different classes.

2. The second point raised by these results has to do with the relative importance of a band selection capability. Notice from Table 6 that the overallclassification performance for the preferred set of spectral bands was 90.1 percent. This is more than 10 percent higher than the same performance figure for the reference data (ERTS simulated channels). Thus, one may say from the data analysist's view point that being required to give up the capability to tailor the band selection to the particular classification to be carried out is a more serious effect than accepting degrading effects in the data due to a data compression algorithm. This can be seen more clearly as follows:

The feature selection algorithm implemented in the LARSYSAA programming system computes the relative separability of each class pair for each possible four-tuple of spectral bands. Table 11 shows the results of applying this algorithm to this classification task. The numbers on the right of Table 11 are the numbers indicating the relative separability of the class pairs. Classes are indicated by a single symbol: "S" for soybeans, "C" for corn, "W" for wheat, "A" for alfalfa, etc. The four-tuple of features (spectral bands) are then rank-ordered based upon the average of these interclass separability measures. Thus, it is seen that bands 1, 9, 11 and 12 were selected as the best feature sets and bands numbered 6, 9, 11 and 12 which are the ones most nearly matching the ERTS channels are second.[1]

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[1] In the case of an actual satellite, however, channel 1 would probably not be as useful as it appears to be here since it is well into the blue portion of the spectrum and from space there would be considerable blue scattering. These results tend to bear out the choice that the ERTS spectral bands are generally a good set.

However, it is possible to further tailor the band selection to the classification task by using additional options available with the feature selection algorithm. Note that in Table 11 some of the interclass pair separabilities are very large indicating very obvious separability; on the other hand, other interclass separability measures are quite small. It would be desirable to pick feature sets based on the possibility of increasing the separability of the more difficult interclass pairs at the expense of the classes with more obvious separability. In order to do this, the feature selection algorithm has been provided with an option permitting the imposing of a maximum interclass separability measure which will be considered for the purpose of rank ordering the four-tuples. Table 12 shows the results of using a maximum of 200. Note that the preferred feature set now becomes 1, 6, 10 and 12 and that the ERTS simulated channels 6, 9, 11 and 12 become 55th in ranking.

This validity of this re-ranking is borne out in the difference in overall accuracy ultimately obtained in the two classifications, 90.1 percent for channels 1, 6, 10 and 12 as compared to 79.7 percent for the ERTS channels 6, 9, 11 and 12.[1]

Thus, by being forced to a suboptimum choice of spectral bands an overall 10% accuracy loss occurred, and the increased loss in accuracy due to data compression was only an additional 1.2 percent in the case of algorithm #3 or 3.2 percent for algorithm one. Figure 3 shows a performance comparison for the preferred bands, the ERTS bands and the ERTS bands with compression number 1.

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[1] From these results one might tend to conclude that the ERTS channels, which are undoubtedly the best possible set of bands in general, may be considerably suboptimum in specific cases.

As a matter of speculation, there is some reason to believe that the use of sub-optimum features in this test may well be compressing the range over which the performance figures for the various data compression algorithms distributed themselves. It would be a desirable experiment to repeat the tests used in this study with the optimum set of features so as to get a clear view of the effects of data compression alone.

Class Separability Measure
(No Maximum)

Rank	Spectral Bands	Average Separability	Individual Class Separability SC	SW	SA	WR	WY	. . .
1	1, 9, 11, 12	444	25	190	188	620	58	
-ERTS- 2	6, 9, 11, 12	428	26	177	229	630	208	
3	2, 9, 11, 12	423	24	151	182	619	58	
4	5, 9, 11, 12	420						
5	8, 9, 11, 12							
	.							
	.							
	.							

Table 11.

Class Separability Measure
(Maximum = 200)

Rank	Spectral Bands	Average Separability	Individual Class Separability SC	SW	SA	WR	WY	. . .
1	1, 6, 10, 12	155	34	200	196	200	180	
2	1, 6, 10, 11	154	34	200	192	200	183	
3	1, 6, 9, 12	153	26	200	193	200	200	
4	1, 6, 9, 11	153	27	200	190	200	200	
	.							
	.							
	.							
-ERTS 55	6, 9, 11, 12	145	26	177	200	200	200	
	.							
	.							
	.							

Table 12.

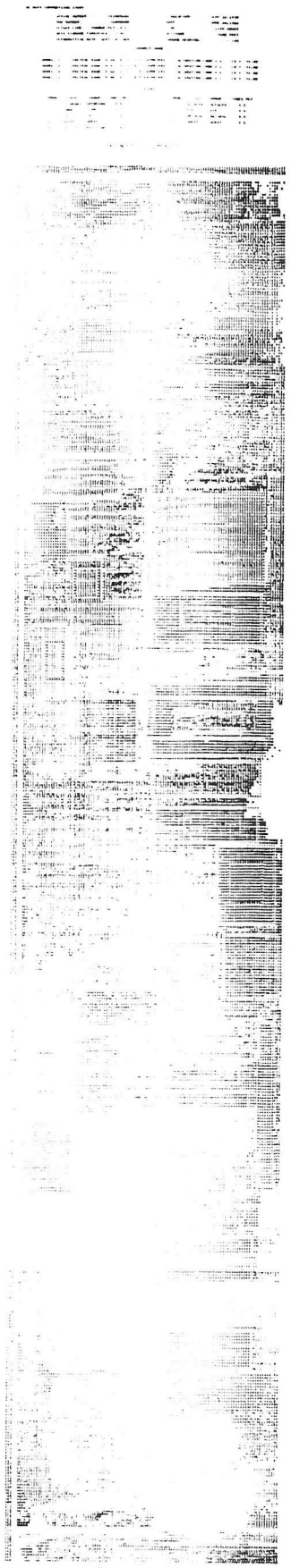


Figure 1. Classification Results of Test Flight Line Using Preferred Channels

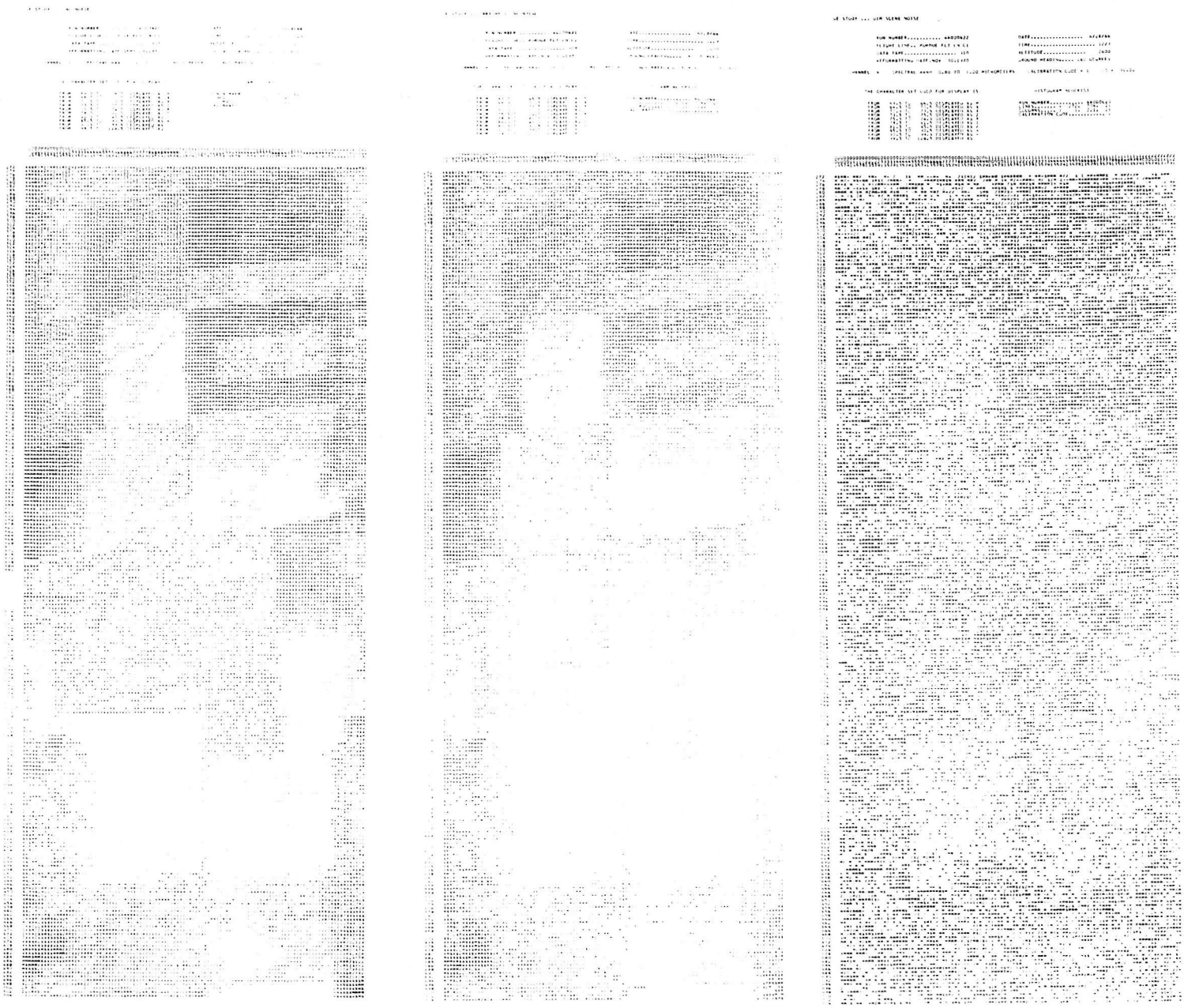


Figure 2. Pictorial Printouts of Reference Data (0.8-1.0 Omm Channel) with No Noise, Noise Level 1 and Noise Level 2

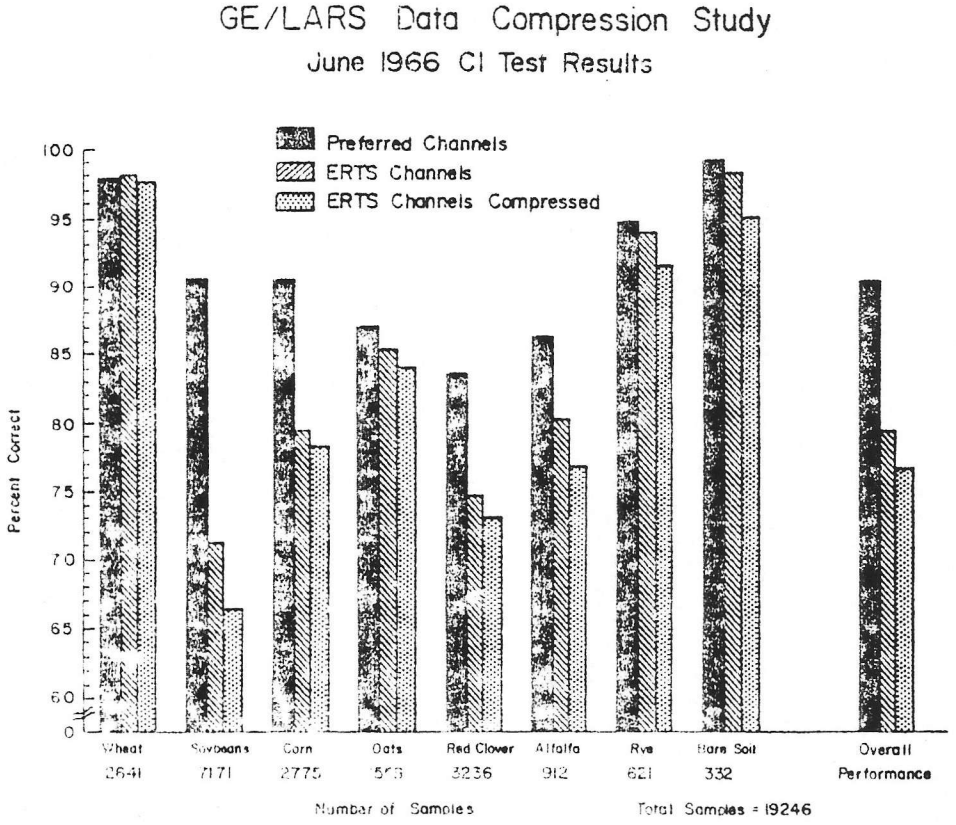


Figure 3. Performance Comparison of Preferred Channels, ERTS Channels and ERTS Channels with Compression #1.

APPENDIX A: Compression Algorithm Number 4

1. Read into temporary store the first 18 pixel signal levels for each of bands 1,2,3,4 as follows:

   a. Band 1: (1) Actual signal levels for pixels 1,4,7,10,13, 16
      (2) For pixels 2,3 - same level as for pixel 1
      (3) For pixels 5,6 - same level as for pixel 4
      (4) etc. for pixels 8,9; 11,12; 14,15; 17,18

   b. Band 2: Actual signal levels for all 18 pixels

   c. Band 3: Same procedure as for step 1a. (Band 1)

   d. Band 4: Same procedure as for step 1a. (Band 1)

2. For the stored signals, measure the difference between the maximum and minimum signal levels in each band. Label these differences D_1, D_2, D_3, and D_4 for bands 1,2,3,4 respectively.

3. Do either or both D_1 or D_2 exceed 32? If "yes" go to step 4.

   If "no" go to step 5.

4. Modify the stored pixel signal levels for Band 1 by adding 17* to the level of every third pixel stored for Band 2 (i.e. pixels 1,4,7,10,13,16), and place the result for each of these six pixels in the appropriate storage cell for Band 1. Then modify the other pixel signals in Band 1 so that pixels 2,3 have same level as pixel 1, pixels 5,6 same as pixel 4, etc. Do not modify the signal levels stored for Band 2.

5. Do either or both D_3 or D_4 exceed 32? If "yes", go to step 6. If "no", go to step 7.

---

* Note: These modifications pertain only to Mission File No. 66000600. Other modifications, derived from the flight data, will be used in other missions.

6. Modify the stored pixel signal levels for Band 4 as follows: Find the value of each pixel signal level stored in Band 3. For each of these 18 values, multiply by (2/3) and add 12.* Place the result for each pixel in the appropriate storage cell for Band 4. Round off to nearest integer. Do not modify the signal levels stored for Band 3.

7. Printout for the new data tape for Purdue the pixel signal levels now stored for pixels 1 to 18 in each of the four bands.

8. Repeat steps 1 to 7 for the next 18 pixel signals in each of the four bands.

9. Continue step 8 until 11 segments of 18 pixel signals in each band have been processed. Then repeat steps 1 to 7 for the last 24 pixel signals in each band. (That is, the last segment in the line will contain 24 pixels rather than 18). The procedure of step 1 will have to be extended to 24 pixels for the last segment, of course.

10. Proceed to line 2 and repeat steps 1 to 9, except that step 1 is modified as follows (and step 4 is adjusted to correspond to it):

    a. Band 1:
       (1) Actual signal levels for pixels 2,5,8,11,14,17
       (2) For pixels 1,3 - same level as for pixel 2
       (3) For pixels 4,6 - same level as for pixel 5
       (4) etc. for pixels 7,9; 10,12; 13,15; 16,18
       (5) Extend the procedure to 24 pixels for the last segment.

    b. Band 2: Actual signal levels for all 18 or 24 pixels.

    c. Band 3: Same procedure as for step 10a (Band 1).

    d. Band 4: Same procedure for step 10a (Band 1).

11. Proceed to line 3 and repeat steps 1 to 9, except that step 1 is modified as follows (and step 4 is adjusted to correspond to it):

    a. Band 1:
       (1) Actual signal levels for pixels 3,6,9,12,15,18
       (2) For pixels 1,2 - same level as for pixel 3
       (3) For pixels 4,5 - same level as for pixel 6
       (4) etc. for pixels 7,8; 10,11; 13,14; 16, 17
       (5) Extend the procedure to 24 pixels for the last segment.

    b. Band 2: Actual signal levels for all 18 or 24 pixels.

    c. Band 3: Same procedure as for step 11a (Band 1).

    d. Band 4: Same procedure as for step 11a (Band 1).

12. Proceed to line 4 and repeat steps 1 to 9 (same procedure as for line 1).

13. Proceed to line 5 and do the same as in step 10 (same procedure as for line 2).

14. Proceed to line 6 and do the same as in step 11 (same procedure as for line 3).

15. Continue the cyclic procedure to the end of the flight run:

Line 7,10,13,16----	same procedure as for line 1
Line 8,11,14,17----	same procedure as for line 2
Line 9,12,15,18----	same procedure as for line 3

This completes the processing for compression - reconstruction and should result in a tape which can be sent to Purdue.

16. As a separate processing output (not to go to Purdue), provide three totals for the entire flight run as follows:

    a. The number of occasions (line segments) where either or both D_1 or D_2 exceed 32. (If both exceed 32, that is only one occasion, and should not be counted as two).

    b. The number of occasions (line segments) where either or both D_3 or D_4 exceed 32. (If both exceed 32, that is only one occasion and should not be counted as two).

    c. The total number of segments in the entire flight run (This is 12 segments x number of lines).

APPENDIX B: CLASSIFICATION RESULTS IN TERMS OF TEST CLASS PERFORMANCE

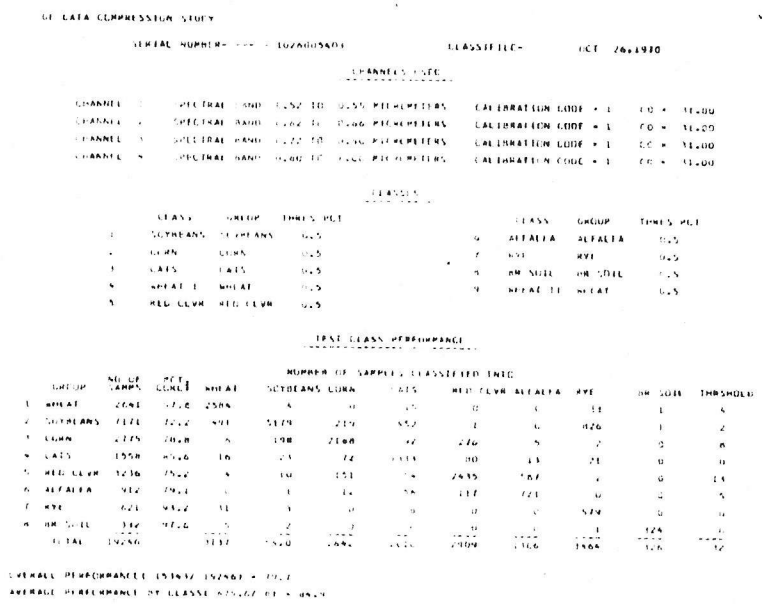


Table B-1. Test Class Performance - Reference Data, No Noise

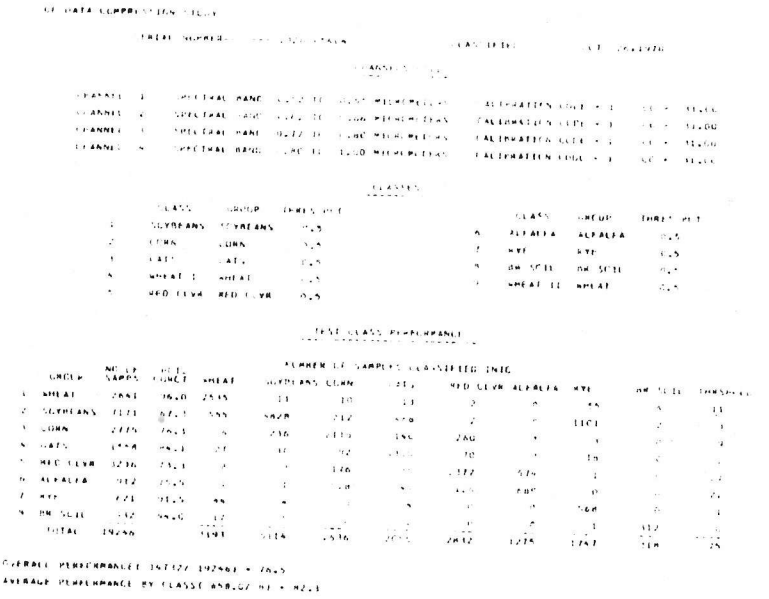


Table B-2. Test Class Performance - Compression #1, No Noise

GE DATA COMPRESSION STUDY

SERIAL NUMBER-------- 1201009405 CLASSIFIED- DEC 2,1970

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.52 TO 0.55 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 2	SPECTRAL BAND 0.62 TO 0.66 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 3	SPECTRAL BAND 0.72 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00

CLASSES

	CLASS	GROUP	THRES PCT		CLASS	GROUP	THRES PCT
1	SOYBEANS	SOYBEANS	0.5	6	ALFALFA	ALFALFA	0.5
2	CORN	CORN	0.5	7	RYE	RYE	0.5
3	OATS	OATS	0.5	8	BR SOIL	BR SOIL	0.5
4	WHEAT I	WHEAT	0.5	9	WHEAT II	WHEAT	0.5
5	RED CLVR	RED CLVR	0.5				

TEST CLASS PERFORMANCE

	GROUP	NO OF SAMPS	PCT CORCT	NUMBER OF SAMPLES CLASSIFIED INTO WHEAT	SOYBEANS	CORN	OATS	RED CLVR	ALFALFA	RYE	BR SOIL	THRSHOLD
1	WHEAT	2691	96.5	2589	11	11	14	3	0	44	1	8
2	SOYBEANS	7171	69.7	445	4997	258	415	1	0	1051	0	4
3	CORN	2775	76.9	5	246	2135	187	188	6	0	0	10
4	OATS	1558	88.1	26	18	112	1310	69	9	13	0	3
5	RED CLVR	3236	67.0	11	1	702	82	2168	746	1	0	25
6	ALFALFA	914	76.5	0	2	19	44	145	679	0	0	23
7	RYE	621	91.9	37	4	0	6	0	0	571	0	3
8	BR SOIL	332	95.8	12	2	0	0	0	0	0	318	0
	TOTAL	19246		3081	5279	3237	2058	2572	1482	1680	319	76

OVERALL PERFORMANCE= 14737/ 19246 = 76.5

AVERAGE PERFORMANCE BY CLASS= 656.47/ 8 = 82.0

Table B-3. Test Class Performance - Compression #2, No Noise

GE DATA COMPRESSION STUDY

SERIAL NUMBER-------- 1201009406 CLASSIFIED- DEC 2,1970

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.52 TO 0.55 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 2	SPECTRAL BAND 0.62 TO 0.66 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 3	SPECTRAL BAND 0.72 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00

CLASSES

	CLASS	GROUP	THRES PCT		CLASS	GROUP	THRES PCT
1	SOYBEANS	SOYBEANS	0.5	6	ALFALFA	ALFALFA	0.5
2	CORN	CORN	0.5	7	RYE	RYE	0.5
3	OATS	OATS	0.5	8	BR SOIL	BR SOIL	0.5
4	WHEAT I	WHEAT	0.5	9	WHEAT II	WHEAT	0.5
5	RED CLVR	RED CLVR	0.5				

TEST CLASS PERFORMANCE

	GROUP	NO OF SAMPS	PCT CORCT	NUMBER OF SAMPLES CLASSIFIED INTO WHEAT	SOYBEANS	CORN	OATS	RED CLVR	ALFALFA	RYE	BR SOIL	THRSHOLD
1	WHEAT	2691	70.6	2556	10	12	11	4	0	91	0	13
2	SOYBEANS	7171	70.7	447	5069	182	462	0	0	789	0	2
3	CORN	2775	78.4	6	206	2190	139	237	3	0	0	14
4	OATS	1558	85.9	32	27	76	1338	68	7	15	0	3
5	RED CLVR	3236	73.9	11	3	163	68	2390	570	0	0	31
6	ALFALFA	914	75.7	1	1	13	49	127	690	0	0	31
7	RYE	621	91.1	36	3	0	4	0	0	578	0	0
8	BR SOIL	332	93.4	20	0	0	1	0	0	1	310	0
	TOTAL	19246		3321	5319	2686	2064	2826	1270	1474	310	96

OVERALL PERFORMANCE= 15167/ 19246 = 78.5

AVERAGE PERFORMANCE BY CLASS= 667.47/ 8 = 83.4

Table B-4. Test Class Performance - Compression #3, No Noise

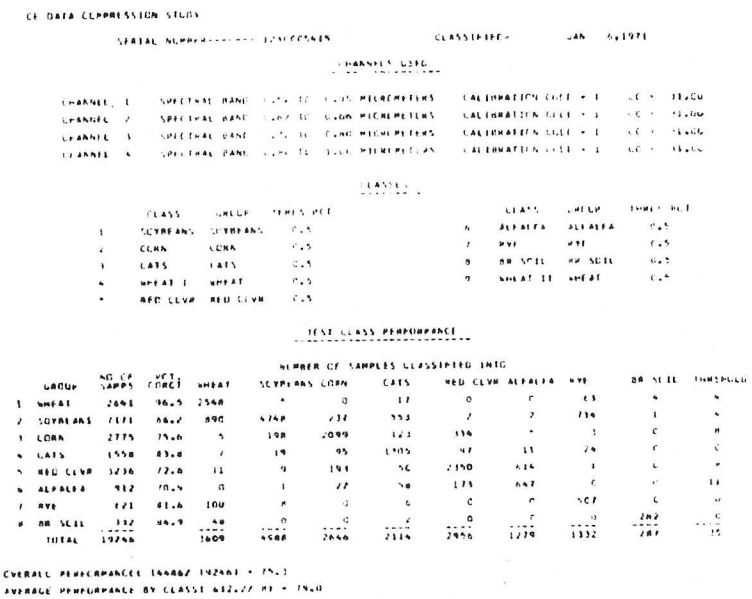


Table B-5. Test Class Performance - Compression #4, No Noise

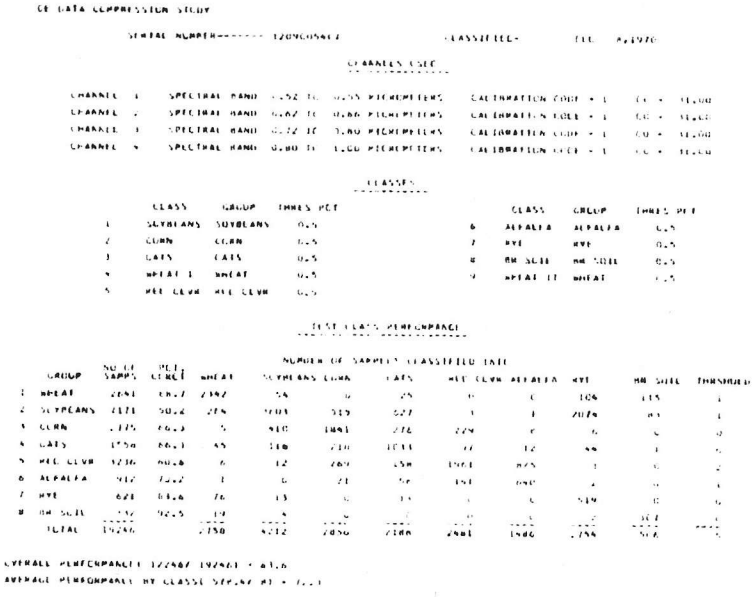
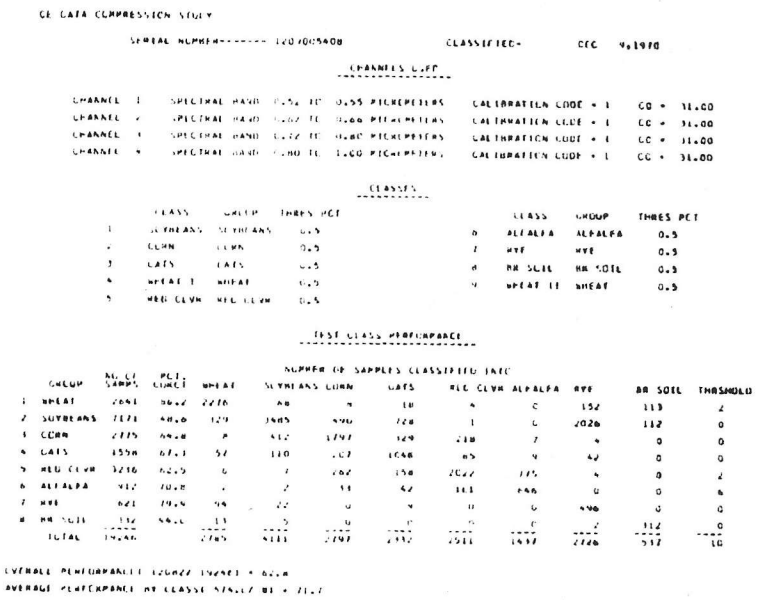


Table B-6. Test Class Performance - Reference Data, Noise Level 1



GE DATA COMPRESSION STUDY

SCENE NUMBER------- 120/0C5408 CLASSIFIED- CEC 9.1970

CHANNELS USED

CHANNEL 1 SPECTRAL BAND 0.52 TO 0.55 MICROMETERS CALIBRATION CODE = 1 CO = 31.00
CHANNEL 2 SPECTRAL BAND 0.62 TO 0.66 MICROMETERS CALIBRATION CODE = 1 CO = 31.00
CHANNEL 3 SPECTRAL BAND 0.72 TO 0.80 MICROMETERS CALIBRATION CODE = 1 CO = 31.00
CHANNEL 4 SPECTRAL BAND 0.80 TO 1.00 MICROMETERS CALIBRATION CODE = 1 CO = 31.00

CLASSES

	CLASS	GROUP	THRES PCT		CLASS	GROUP	THRES PCT
1	SOYBEANS	SOYBEANS	0.5	6	ALFALFA	ALFALFA	0.5
2	CORN	CORN	0.5	7	RYE	RYE	0.5
3	OATS	OATS	0.5	8	BR SOIL	BR SOIL	0.5
4	WHEAT I	WHEAT	0.5	9	WHEAT II	WHEAT	0.5
5	RED CLVR	RED CLVR	0.5				

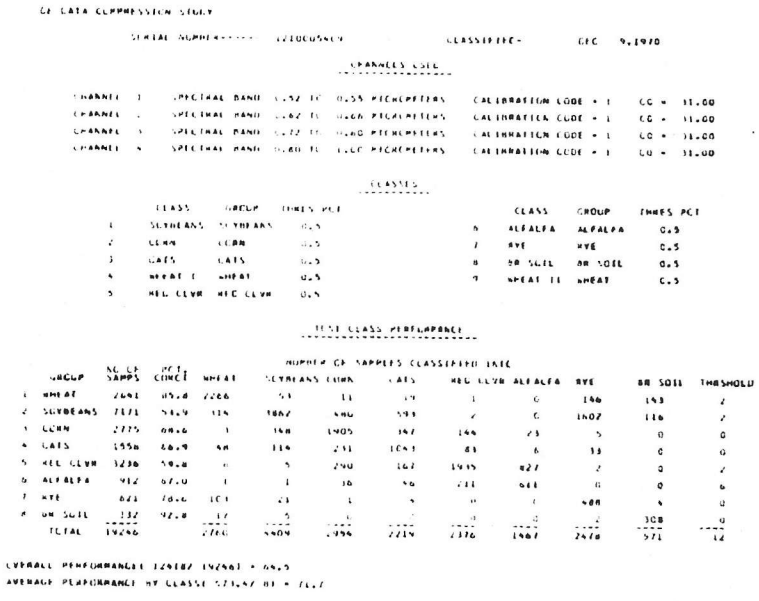
TEST CLASS PERFORMANCE

NUMBER OF SAMPLES CLASSIFIED INTO

	GROUP	NO. OF SAMPS	PCT CORRECT	WHEAT	SOYBEANS	CORN	OATS	RED CLVR	ALFALFA	RYE	BR SOIL	THRSHOLD
1	WHEAT	2691	96.2	2278	48	4	18	4	0	152	113	2
2	SOYBEANS	7171	48.6	129	3485	490	728	1	0	2026	112	0
3	CORN	2775	66.8	8	412	1797	329	218	7	4	0	0
4	OATS	1558	67.1	57	110	207	1048	85	4	42	0	0
5	RED CLVR	3236	62.5	6	7	262	158	2027	775	4	0	2
6	ALFALFA	912	70.8	4	2	58	42	161	646	0	0	6
7	RYE	621	79.6	96	22	0	4	0	0	496	0	0
8	BR SOIL	132	58.3	33	5	0	0	0	0	2	312	0
	TOTAL	19260		2765	4121	2747	2352	2511	1437	2726	537	10

OVERALL PERFORMANCE= 12082/ 19260 = 62.7%
AVERAGE PERFORMANCE BY CLASSES 575.47 81 = 71.7

Table B-7. Test Class Performance - Compression #1, Noise Level 1



GE DATA COMPRESSION STUDY

SCENE NUMBER------ 120CC5SCV CLASSIFIED- CEC 9.1970

CHANNELS USED

CHANNEL 1 SPECTRAL BAND 0.52 TO 0.55 MICROMETERS CALIBRATION CODE = 1 CO = 31.00
CHANNEL 2 SPECTRAL BAND 0.62 TO 0.66 MICROMETERS CALIBRATION CODE = 1 CO = 31.00
CHANNEL 3 SPECTRAL BAND 0.72 TO 0.80 MICROMETERS CALIBRATION CODE = 1 CO = 31.00
CHANNEL 4 SPECTRAL BAND 0.80 TO 1.00 MICROMETERS CALIBRATION CODE = 1 CO = 31.00

CLASSES

	CLASS	GROUP	THRES PCT		CLASS	GROUP	THRES PCT
1	SOYBEANS	SOYBEANS	0.5	6	ALFALFA	ALFALFA	0.5
2	CORN	CORN	0.5	7	RYE	RYE	0.5
3	OATS	OATS	0.5	8	BR SOIL	BR SOIL	0.5
4	WHEAT I	WHEAT	0.5	9	WHEAT II	WHEAT	0.5
5	RED CLVR	RED CLVR	0.5				

TEST CLASS PERFORMANCE

NUMBER OF SAMPLES CLASSIFIED INTO

	GROUP	NO. OF SAMPS	PCT CORRECT	WHEAT	SOYBEANS	CORN	OATS	RED CLVR	ALFALFA	RYE	BR SOIL	THRSHOLD
1	WHEAT	2691	85.8	2286	51	11	19	1	0	146	143	2
2	SOYBEANS	7171	54.9	134	3862	490	593	2	0	1407	116	2
3	CORN	2775	68.6	1	148	1905	167	144	23	5	0	0
4	OATS	1558	66.9	48	114	291	1041	81	6	33	0	0
5	RED CLVR	3236	59.8	0	5	290	167	1935	827	2	0	2
6	ALFALFA	912	67.0	1	1	38	46	211	611	0	0	6
7	RYE	621	78.6	101	21	1	5	0	0	488	4	0
8	BR SOIL	132	92.8	17	5	0	0	0	0	2	308	0
	TOTAL	19260		2760	4409	2994	2219	2376	1467	2478	571	12

OVERALL PERFORMANCE= 12018/ 19260 = 62.4
AVERAGE PERFORMANCE BY CLASSES 571.47 81 = 71.7

Table B-8. Test Class Performance - Compression #2, Noise Level 1

GE DATA COMPRESSION STUDY

SERIAL NUMBER------- 1210005410 CLASSIFIED- CCC 9.1970

CHANNELS USED

CHANNEL 1	SPECTRAL BAND	0.52 TO 0.55 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 2	SPECTRAL BAND	0.62 TO 0.66 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 3	SPECTRAL BAND	0.72 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 4	SPECTRAL BAND	0.80 TO 1.00 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00

CLASSES

	CLASS	GROUP	THRES PCT		CLASS	GROUP	THRES PCT
1	SOYBEANS	SOYBEANS	0.5	6	ALFALFA	ALFALFA	0.5
2	CORN	CORN	0.5	7	RYE	RYE	0.5
3	OATS	OATS	0.5	8	BR SOIL	BR SOIL	0.5
4	WHEAT I	WHEAT	0.5	9	WHEAT II	WHEAT	0.5
5	RED CLVR	RED CLVR	0.5				

TEST CLASS PERFORMANCE

	GROUP	NO OF SAMPS	PCT CORCT	NUMBER OF SAMPLES CLASSIFIED INTO: WHEAT	SOYBEANS	CORN	OATS	RED CLOVER	ALFALFA	RYE	BR SOIL	THRSHOLD
1	WHEAT	2641	91.5	2417	32	13	21	3	0	110	41	4
2	SOYBEANS	7171	56.5	301	4050	359	625	1	0	1819	20	0
3	CORN	2775	70.9	5	336	1967	262	199	3	1	0	0
4	OATS	1550	76.2	58	61	156	1187	71	3	38	0	7
5	RED CLVR	3236	65.9	6	7	210	125	2132	750	1	0	5
6	ALFALFA	912	73.2	3	1	20	54	178	669	0	0	9
7	RYE	621	85.2	73	14	0	5	0	0	529	0	0
8	BR SOIL	332	96.1	10	1	0	0	0	0	2	319	0
	TOTAL	19246		2873	4502	2723	2277	2584	1405	2682	380	25

OVERALL PERFORMANCE: (12502/ 19246) = 68.8

AVERAGE PERFORMANCE BY CLASS: (613.67/ 8) = 76.7

Table B-9. Test Class Performance - Compression #3, Noise Level 1

GE DATA COMPRESSION STUDY

SERIAL NUMBER------- 1210005410 CLASSIFIED- JAN 9.1970

CHANNELS USED

CHANNEL 1	SPECTRAL BAND	0.52 TO 0.55 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 2	SPECTRAL BAND	0.62 TO 0.66 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 3	SPECTRAL BAND	0.72 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 4	SPECTRAL BAND	0.80 TO 1.00 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00

CLASSES

	CLASS	GROUP	THRES PCT		CLASS	GROUP	THRES PCT
1	SOYBEANS	SOYBEANS	0.5	6	ALFALFA	ALFALFA	0.5
2	CORN	CORN	0.5	7	RYE	RYE	0.5
3	OATS	OATS	0.5	8	BR SOIL	BR SOIL	0.5
4	WHEAT I	WHEAT	0.5	9	WHEAT II	WHEAT	0.5
5	RED CLVR	RED CLVR	0.5				

TEST CLASS PERFORMANCE

	GROUP	NO OF SAMPS	PCT CORCT	NUMBER OF SAMPLES CLASSIFIED INTO: WHEAT	SOYBEANS	CORN	OATS	RED CLVR	ALFALFA	RYE	BR SOIL	THRSHOLD
1	WHEAT	2641	80.6	2130	28	0	23	0	0	257	177	2
2	SOYBEANS	7171	50.1	520	3590	507	659	6	3	1781	104	1
3	CORN	2775	68.0	6	151	1832	286	240	20	4	2	1
4	OATS	1550	64.8	35	143	214	1016	110	14	43	1	1
5	RED CLVR	3236	61.1	6	19	108	122	1985	280	2	1	1
6	ALFALFA	912	64.5	0	1	28	52	156	588	0	1	1
7	RYE	621	77.5	116	11	0	5	0	0	481	1	1
8	BR SOIL	332	89.5	32	1	0	0	0	0	3	297	1
	TOTAL	19246		2857	4218	2889	2153	2497	1413	2571	584	12

OVERALL PERFORMANCE: (11012/ 19246) = 57.2

AVERAGE PERFORMANCE BY CLASS: (549.82/ 8) = 68.7

Table B-10. Test Class Performance - Compression #4, Noise Level 1

GE DATA COMPRESSION STUDY

SERIAL NUMBER------- 1211005411 CLASSIFIED- DEC 9,1970

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.52 TO 0.55 MICROMETERS	CALIBRATION CODE = 1	CO = 31.00
CHANNEL 2	SPECTRAL BAND .62 TO 0.66 MICROMETERS	CALIBRATION CODE = 1	CO = 31.00
CHANNEL 3	SPECTRAL BAND 0.72 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 31.00
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.00 MICROMETERS	CALIBRATION CODE = 1	CO = 31.00

CLASSES

	CLASS	GROUP	THRES PCT		CLASS	GROUP	THRES PCT
1	SOYBEANS	SOYBEANS	0.5	6	ALFALFA	ALFALFA	0.5
2	CORN	CORN	0.5	7	RYE	RYE	0.5
3	OATS	OATS	0.5	8	BR SOIL	BR SOIL	0.5
4	WHEAT I	WHEAT	0.5	9	WHEAT II	WHEAT	0.5
5	RED CLVR	RED CLVR	0.5				

TEST CLASS PERFORMANCE

	GROUP	NO OF SAMPS	PCT CORCT	NUMBER OF SAMPLES CLASSIFIED INTO: WHEAT	SOYBEANS	CORN	OATS	RED CLVR	ALFALFA	RYE	BR SOIL	THRSHOLD
1	WHEAT	2641	95.3	2517	2	0	25	0	0	40	52	5
2	SOYBEANS	7171	78.1	123	5239	224	316	4	0	986	11	43
3	CORN	2775	74.2	6	198	2059	159	280	66	2	0	5
4	OATS	1558	77.0	18	106	111	1200	92	6	21	0	2
5	RED CLVR	3236	74.6	4	19	105	55	2415	554	4	0	6
6	ALFALFA	912	78.2	0	12	45	32	107	713	0	0	1
7	RYE	621	90.2	39	14	0	5	0	0	560	3	0
8	BR SOIL	332	97.3	1	2	0	0	0	0	2	323	4
	TOTAL	19246		2958	5586	2626	1790	2898	1339	1632	389	48

OVERALL PERFORMANCE= 150287 192461 = 78.1

AVERAGE PERFORMANCE BY CLASS= 659.97 81 = 82.5

Table B-11. Test Class Performance - Reference Data, Noise Level 2

GE DATA COMPRESSION STUDY

SERIAL NUMBER------- 1211005412 CLASSIFIED- DEC 10,1970

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.52 TO 0.55 MICROMETERS	CALIBRATION CODE = 1	CO = 31.00
CHANNEL 2	SPECTRAL BAND .62 TO 0.66 MICROMETERS	CALIBRATION CODE = 1	CO = 31.00
CHANNEL 3	SPECTRAL BAND 0.72 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 31.00
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.00 MICROMETERS	CALIBRATION CODE = 1	CO = 31.00

CLASSES

	CLASS	GROUP	THRES PCT		CLASS	GROUP	THRES PCT
1	SOYBEANS	SOYBEANS	0.5	6	ALFALFA	ALFALFA	0.5
2	CORN	CORN	0.5	7	RYE	RYE	0.5
3	OATS	OATS	0.5	8	BR SOIL	BR SOIL	0.5
4	WHEAT I	WHEAT	0.5	9	WHEAT II	WHEAT	0.5
5	RED CLVR	RED CLVR	0.5				

TEST CLASS PERFORMANCE

	GROUP	NO OF SAMPS	PCT CORCT	NUMBER OF SAMPLES CLASSIFIED INTO: WHEAT	SOYBEANS	CORN	OATS	RED CLVR	ALFALFA	RYE	BR SOIL	THRSHOLD
1	WHEAT	2641	48.0	1268	268	89	188	18	2	293	515	0
2	SOYBEANS	7171	16.7	1023	1197	1046	951	190	122	1799	838	0
3	CORN	2775	16.6	138	415	1021	438	421	149	136	63	0
4	OATS	1558	24.6	196	152	421	383	191	72	171	72	0
5	RED CLVR	3236	42.0	17	92	595	276	1360	820	42	14	0
6	ALFALFA	912	50.3	9	7	103	66	248	462	16	1	0
7	RYE	621	40.1	158	16	17	55	1	14	249	91	0
8	BR SOIL	332	51.5	68	27	8	17	0	0	41	171	0
	TOTAL	19246		2867	2194	3200	2374	2429	1640	2747	1765	0

OVERALL PERFORMANCE= 91117 192461 = 51.8

AVERAGE PERFORMANCE BY CLASS= 510.57 81 = 18.8

Table B-12. Test Class Performance - Compression #1, Noise Level 2

GE DATA COMPRESSION STUDY

SERIAL NUMBER-------- 1211005813 CLASSIFIED- DEC 10,1970

CHANNELS USED

CHANNEL 1	SPECTRAL BAND	0.52 TO 0.55 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 2	SPECTRAL BAND	0.62 TO 0.66 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 3	SPECTRAL BAND	0.72 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 4	SPECTRAL BAND	0.80 TO 1.00 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00

CLASSES

	CLASS	GROUP	THRES PCT		CLASS	GROUP	THRES PCT
1	SOYBEANS	SOYBEANS	0.5	6	ALFALFA	ALFALFA	0.5
2	CORN	CORN	0.5	7	RYE	RYE	0.5
3	OATS	OATS	0.5	8	BR SOIL	BR SOIL	0.5
4	WHEAT I	WHEAT	0.5	9	WHEAT II	WHEAT	0.5
5	RED CLVR	RED CLVR	0.5				

TEST CLASS PERFORMANCE

NUMBER OF SAMPLES CLASSIFIED INTO

	GROUP	NO OF SAMPS	PCT CORCT	WHEAT	SOYBEANS	CORN	OATS	RED CLVR	ALFALFA	RYE	BR SOIL	THRESHOLD
1	WHEAT	2691	41.9	1127	294	11	9	1	0	832	402	5
2	SOYBEANS	7171	98.8	661	7090	469	1129	3	0	1096	365	12
3	CORN	2775	62.5	9	258	1734	424	286	33	25	1	5
4	OATS	1558	36.6	31	284	549	571	74	8	41	0	0
5	RED CLVR	3236	63.2	2	15	536	66	2046	560	3	0	10
6	ALFALFA	912	47.4	0	4	80	28	166	432	0	0	2
7	RYE	621	41.1	145	152	0	11	0	0	255	58	0
8	BR SOIL	332	74.4	53	10	0	0	0	0	19	247	3
	TOTAL	19246		2008	8515	3379	2236	2776	1033	2009	1253	37

OVERALL PERFORMANCE= 9890/ 19246 = 51.4

AVERAGE PERFORMANCE BY CLASS= 419.47 81 = 52.0

Table B-13. Test Class Performance - Compression #2, Noise Level 2

GE DATA COMPRESSION STUDY

SERIAL NUMBER-------- 1211005414 CLASSIFIED- DEC 10,1970

CHANNELS USED

CHANNEL 1	SPECTRAL BAND	0.52 TO 0.55 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 2	SPECTRAL BAND	0.62 TO 0.66 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 3	SPECTRAL BAND	0.72 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00
CHANNEL 4	SPECTRAL BAND	0.80 TO 1.00 MICROMETERS	CALIBRATION CODE = 1	CO =	31.00

CLASSES

	CLASS	GROUP	THRES PCT		CLASS	GROUP	THRES PCT
1	SOYBEANS	SOYBEANS	0.5	6	ALFALFA	ALFALFA	0.5
2	CORN	CORN	0.5	7	RYE	RYE	0.5
3	OATS	OATS	0.5	8	BR SOIL	BR SOIL	0.5
4	WHEAT I	WHEAT	0.5	9	WHEAT II	WHEAT	0.5
5	RED CLVR	RED CLVR	0.5				

TEST CLASS PERFORMANCE

NUMBER OF SAMPLES CLASSIFIED INTO

	GROUP	NO OF SAMPS	PCT CORCT	WHEAT	SOYBEANS	CORN	OATS	RED CLVR	ALFALFA	RYE	BR SOIL	THRESHOLD
1	WHEAT	2691	59.4	1598	146	15	120	2	2	291	516	1
2	SOYBEANS	7171	11.2	663	2279	1057	1892	19	5	1640	371	1
3	CORN	2775	51.4	15	426	1426	447	208	57	90	6	0
4	OATS	1558	17.8	124	209	117	586	244	26	115	17	0
5	RED CLVR	3236	50.5	8	41	608	259	1635	679	4	2	0
6	ALFALFA	912	51.0	1	6	45	15	269	483	2	0	0
7	RYE	621	43.3	147	63	11	41	1	0	269	87	0
8	BR SOIL	332	55.4	54	17	1	5	0	0	41	184	1
	TOTAL	19246		2611	3181	3519	3566	2380	1252	2462	1203	3

OVERALL PERFORMANCE= 10747/ 19246 = 55.8

AVERAGE PERFORMANCE BY CLASS= 382.17 81 = 47.8

Table B-14. Test Class Performance - Compression #3, Noise Level 2

GE DATA COMPRESSION STUDY

SERIAL NUMBER------- 123CCC5413 CLASSIFIED- JAN 8,1981

CHANNELS USED

CHANNEL 1	SPECTRAL BAND	0.52 TO 0.55 MICROMETERS	CALIBRATION CODE = 1	CC =	31.00
CHANNEL 2	SPECTRAL BAND	0.62 TO 0.66 MICROMETERS	CALIBRATION CODE = 1	CC =	31.00
CHANNEL 3	SPECTRAL BAND	0.72 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CC =	31.00
CHANNEL 4	SPECTRAL BAND	0.80 TO 1.00 MICROMETERS	CALIBRATION CODE = 1	CC =	31.00

CLASSES

	CLASS	GROUP	THRES PCT		CLASS	GROUP	THRES PCT
1	SOYBEANS	SOYBEANS	0.5	6	ALFALFA	ALFALFA	0.5
2	CORN	CORN	0.5	7	RYE	RYE	0.5
3	OATS	OATS	0.5	8	BR SOIL	BR SOIL	0.5
4	WHEAT I	WHEAT	0.5	9	WHEAT II	WHEAT	0.5
5	RED CLVR	RED CLVR	0.5				

TEST CLASS PERFORMANCE

	GROUP	NO. OF SAMPS	PCT CORRT	NUMBER OF SAMPLES CLASSIFIED INTO: WHEAT	SOYBEANS	CORN	OATS	RED CLVR	ALFALFA	RYE	BR SOIL	THRSHOLD
1	WHEAT	2861	93.7	2675	47	2	38	0	0	18	35	26
2	SOYBEANS	7171	40.9	1470	2932	54	2944	0	4	155	8	4
3	CORN	2779	42.5	8	129	1180	1256	99	93	4	0	11
4	OATS	1558	60.1	29	259	279	937	18	29	12	0	0
5	RED CLVR	1236	18.5	9	9	680	155	516	2040	0	0	4
6	ALFALFA	912	86.6	0	0	28	55	54	770	0	0	0
7	RYE	721	4.8	526	31	0	18	0	0	30	6	10
8	BR SOIL	332	12.7	279	1	0	2	0	0	1	32	7
	TOTAL	19746		4996	3308	2823	5007	710	2936	226	91	67

OVERALL PERFORMANCE= 8900/ 19268 = 46.2

AVERAGE PERFORMANCE BY CLASS= 355.77/ 8 = 44.5

Table B-15. Test Class Performance - Compression #4, Noise Level 2

GE DATA COMPRESSION STUDY

SERIAL NUMBER------- 102A0C5403 CLASSIFIED- OCT 28,1970

CHANNELS USED

CHANNEL 1	SPECTRAL BAND	0.52 TO 0.55 MICROMETERS	CALIBRATION CODE = 1	CC =	31.00
CHANNEL 2	SPECTRAL BAND	0.62 TO 0.66 MICROMETERS	CALIBRATION CODE = 1	CC =	31.00
CHANNEL 3	SPECTRAL BAND	0.72 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CC =	31.00
CHANNEL 4	SPECTRAL BAND	0.80 TO 1.00 MICROMETERS	CALIBRATION CODE = 1	CC =	31.00

CLASSES

	CLASS	GROUP	THRES PCT		CLASS	GROUP	THRES PCT
1	SOYBEANS	SOYBEANS	0.5	6	ALFALFA	ALFALFA	0.5
2	CORN	CORN	0.5	7	RYE	RYE	0.5
3	OATS	OATS	0.5	8	BR SOIL	BR SOIL	0.5
4	WHEAT I	WHEAT	0.5	9	WHEAT II	WHEAT	0.5
5	RED CLVR	RED CLVR	0.5				

TEST CLASS PERFORMANCE

	GROUP	NO. OF SAMPS	PCT CORRT	NUMBER OF SAMPLES CLASSIFIED INTO: WHEAT	SOYBEANS	CORN	OATS	RED CLVR	ALFALFA	RYE	BR SOIL	THRSHOLD
1	WHEAT	5918	97.8	5649	0	0	55	0	0	131	18	6
2	SOYBEANS	27370	71.0	2618	19431	788	1913	8	2	3174	3	13
3	CORN	10515	79.5	11	739	8363	328	1046	17	10	0	31
4	OATS*	5864	85.4	49	77	289	5006	119	40	39	0	5
5	RED CLVR	12197	78.4	12	12	548	209	9096	2168	7	0	37
6	ALFALFA	3375	80.2	0	2	33	186	430	2707	4	0	13
7	RYE	2305	94.0	108	6	0	28	0	0	2163	0	0
8	BR SOIL	1230	98.1	19	2	1	0	0	0	1	1207	0
	TOTAL	72804		13916	20268	10062	7725	10867	4934	5649	1228	105

OVERALL PERFORMANCE= 57750/ 72804 = 79.3

AVERAGE PERFORMANCE BY CLASS= 692.77/ 8 = 86.6

Table B-16. Test Class Performance - Reference Data, Full Sampling Rat

GE DATA COMPRESSION STUDY

SERIAL NUMBER-------- 1026005604 CLASSIFIED- OCT 26,1970

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.52 TO 0.55 MICROMETERS	CALIBRATION CODE = 1	CO = 31.00
CHANNEL 2	SPECTRAL BAND 0.61 TO 0.66 MICROMETERS	CALIBRATION CODE = 1	CO = 31.00
CHANNEL 3	SPECTRAL BAND 0.72 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 31.00
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.00 MICROMETERS	CALIBRATION CODE = 1	CO = 31.00

CLASSES

	CLASS	GROUP	THRES PCT		CLASS	GROUP	THRES PCT
1	SOYBEANS	SOYBEANS	0.5	6	ALFALFA	ALFALFA	0.5
2	CORN	CORN	0.5	7	RYE	RYE	0.5
3	OATS	OATS	0.5	8	BR SOIL	BR SOIL	0.5
4	WHEAT 1	WHEAT	0.5	9	WHEAT II	WHEAT	0.5
5	RED CLVR	RED CLVR	0.5				

TEST CLASS PERFORMANCE

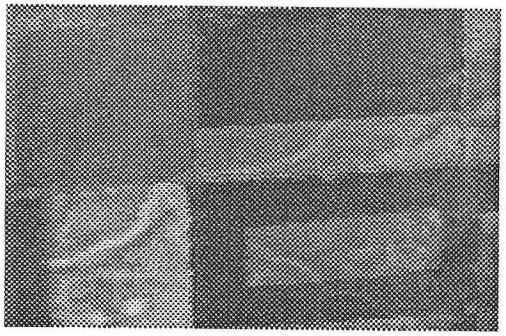
NUMBER OF SAMPLES CLASSIFIED INTO

	GROUP	NO OF SAMPS	PCT CORRECT	WHEAT	SOYBEANS	CORN	OATS	RED CLVR	ALFALFA	RYE	BR SOIL	THRSHOLD
1	WHEAT	9918	96.5	9568	31	27	61	2	6	181	18	30
2	SOYBEANS	27370	66.4	2085	18183	810	1951	9	2	4417	4	9
3	CORN	10515	79.1	11	781	8709	517	858	11	4	0	29
4	OATS	5864	84.6	85	90	197	4925	284	32	65	0	6
5	RED CLVR	12167	73.0	16	17	707	212	8864	2224	4	0	81
6	ALFALFA	1375	77.0	1	2	73	156	466	2599	1	0	79
7	RYE	2385	91.5	144	21	0	17	0	0	2182	0	1
8	BR SOIL	1116	95.1	56	1	0	2	0	0	1	1170	0
	TOTAL	72804		11968	19128	10223	7899	10556	4868	6755	1192	235

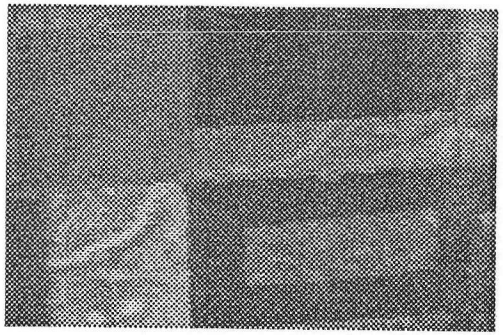
OVERALL PERFORMANCE= 55/CO/ 72804 = 76.5

AVERAGE PERFORMANCE BY CLASS= 661.67 81 = 82.7

Table B-17. Test Class Performance - Compression #1, Full Sampling Rate

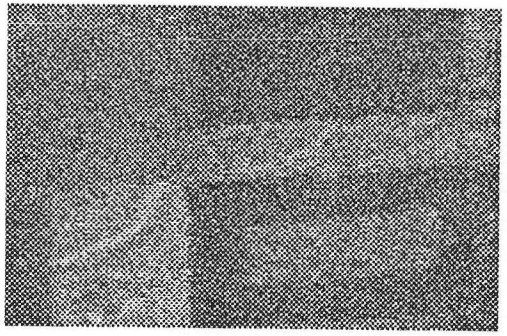


Original Data
97.7%



Low Noise
74.7%

Noise not correlated between channels



High Noise
95%

Higher Noise but Noise Correlated from channel to channel

From David Headgrebe