

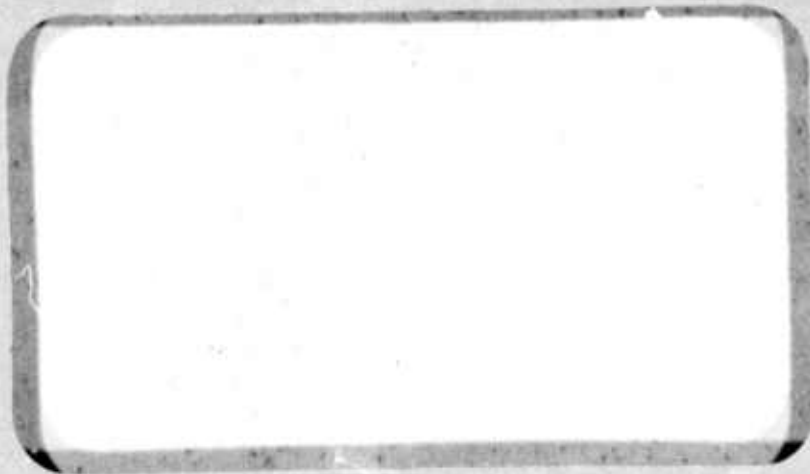
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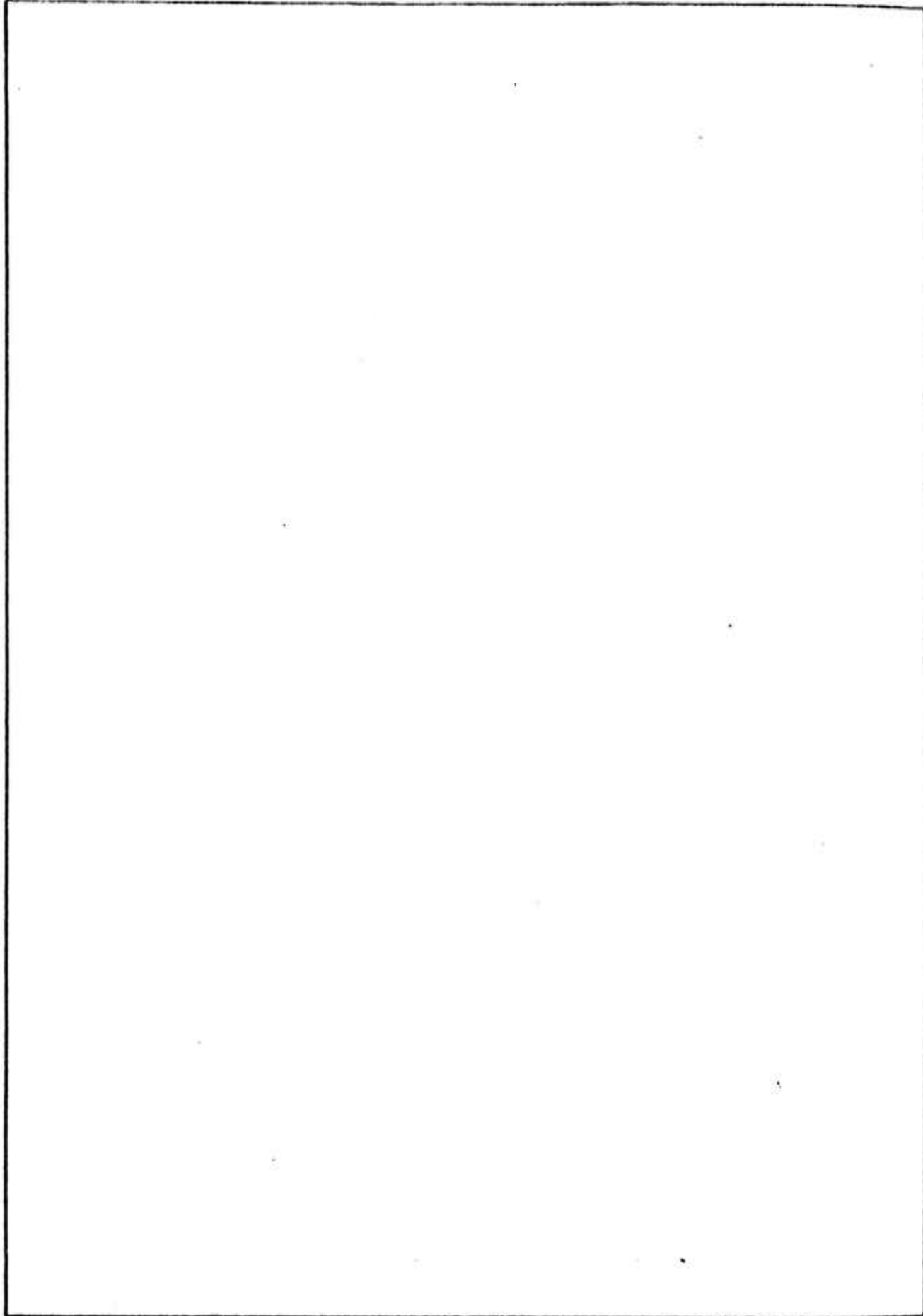
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FINAL REPORT

November 15, 1975

DEVELOPMENT OF TECHNIQUES FOR MULTIPLE DATA STREAM ANALYSIS AND SHORT-TERM FORECASTING VOLUME II

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PREFACE

This report describes research performed for the Defense Advanced Research Projects Agency, Human Resources Research Office, on development of techniques for short-term forecasting and their application within the national security community. It is part of a larger study which deals with event data.

The work reported herein focuses on the development of techniques for forecasting by quantitative analogies. The work builds on prior research devoted to the coding and collection of event data and the development of quantitative indicators for defense analysis. The continuing objective of all research has been to develop event analysis to the point where it can be useful to the national security community as a means for systematically recording, analyzing and forecasting significant international phenomena.

For the past several years, CACI has been engaged in developing and applying techniques for forecasting international economic, military, and political variables relevant to various components of the Department of Defense. By and large, these efforts have concentrated on long-range forecasting, the 10 to 20 year period. Thus, much of the developmental research in the area of forecasting in recent years has focused on capabilities for enhancing the value of long-range strategic policies and plans.

Yet the short range, the period from the immediate time to 2 years out, offers many opportunities to the Department and poses many requirements as well. It is essential that the DoD remain abreast of world political, military and economic affairs in order to anticipate changes in adversary intentions, in threat situations, in opportunities for cooperative initiatives, and in other international conditions which bear on its peace-keeping role. Assessments of such conditions have far-reaching implications for DoD decisions on strategic posture, development of equipment, size and disposition of U.S. military forces and other pivotal matters.

Within the DoD, a prodigious effort and cost is devoted to gathering and interpreting foreign information across the range of subjects and detail pertinent to DoD interests. Supplementary information which can be gleaned from easily available and essentially "free" information resources can be exploited as a cost-effective means of enriching the DoD information base. A large volume of current information on international affairs is continuously reported in publicly available sources emanating from different countries around the world. Specifically, representatives of private and governmental news media collect, report, and interpret information for various news-consuming publics in a manner parallel to, and similar in many ways to, the intelligence function.

Subject to certain processing, this type of information has been shown to have potential as a valuable summary source of ongoing international political and economic information. The processing includes:

1. The coding of narrative accounts of international affairs into continuous and timely streams of quantitative data,
2. The conversion of these data into quantitative indicators which measure and describe selected international political and economic phenomena, and
3. The development of short-term forecasting techniques to enhance the anticipation of future international prospects.

Past and current ARPA programs, which focused on U.S.-produced data sources, have resulted in the development, demonstration, and initial attempts at application of a new technology based on such information processing, called event analysis. While present efforts at application continue, however, compelling opportunities for further research can be identified which would offer more far-reaching bases for application in the DoD. These research opportunities involve the extension of information processing to foreign sources for the eventual purpose of supplementing DoD information on foreign expectations and intentions.

The overall objective of this effort was to apply a variety of techniques or methodologies to these available "free" sources of information to determine the applicability of alternative methodologies for generating short-range forecasts of nations' political and military objectives. Such forecasts, if available, would enable DoD planners and analysts to anticipate changes in adversary intentions, in threat situations, and in opportunities for U.S. initiatives on a near real-time basis. As such, they could provide valuable inputs into a variety of decisions that the Department must make regarding contingency plans, the size and disposition of U.S. military forces, overseas arms sales, the development of new equipments, and so forth. In short, the development of viable short-term forecasting techniques offers the Department opportunities for enhancing the information base upon which reactive decisions are made to a very great extent.

REQUIRED TASKS

In order to investigate short-term forecasting with available data, two tasks had to be performed. Completion of these two tasks enables an evaluation of the usefulness of two broad approaches to short-term forecasting and a judgment as to the directions of basic research needed to upgrade DoD forecasting capabilities for short-range analyses.

Task 1: The Contractor undertook further development of univariate time series analysis as a technique for establishing historical precedents for forecasting. This further development of univariate time series analysis included expansion in the scope of previous research, validation of results, and assessment of utility.

Subtask A: Expansion in the scope of previous research includes experimentation with alternative case samples, alternative time periods, and application of univariate time series analysis to alternate indicators.

Subtask B: Validation of results includes comparison of actual forecasted probability distribution with probability distribution produced by random generators. Further, validation includes comparisons of forecasts previously produced for the 1973-1974 period with actual 1973-1974 outcomes.

Subtask C: Assessment of the utility of invariate time series is based on the preparation and interpretation of sample forecasts for selected regions of the world.

Task 2: The Contractor examined multivariate cross-sectional analysis as a technique for establishing historical precedents for forecasting short-term crises involving the use of military force. Based on the research, probabilistic forecasts of the likelihood of this phenomenon occurring between particular pairs of countries in the near future were produced. The technique was assessed for possible application to other phenomena.

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RESEARCH AND RESULTS

TWO-YEAR FORECASTING BY ANALOGY

Historical analogies are frequently used as the basis for judgmental forecasts. Specifically, if the dimensions of a current situation are perceived to be similar to those of some previous situation, then, other things being equal, the probable outcome of the current situation is assumed to be similar to the actual outcome of its past analogue. The premise of such forecasting is that behavioral patterns exist independent of their time and place of occurrence. In this sense history is assumed to be repetitive and, therefore, to provide a basis for prediction.

In its quantitative form, this approach to forecasting may be pursued both by univariate time series analysis and by multivariate cross-sectional analysis. Univariate time series analysis limits attention to a single variable--that one for which a forecast is sought--and employs a large number of cases to segregate historical patterns and their outcomes. The unique distribution of outcomes associated with an historical pattern is employed as the probabilistic forecast distribution for cases which currently conform to the same pattern.

In previous Defense Advanced Research Projects Agency supported research (CACI, 1974), the first attempts at translating this forecasting approach to quantitative terms yielded promising results. Time series analysis of the histories of Relations and Policy Style measures for sizeable samples of country pairs revealed past patterns of behavior which were associated with statistically significant differences in subsequent outcomes. One set of objectives of the present short-term forecasting research is to attempt to replicate and extend the earlier results, validate forecasts based on the results, and demonstrate the utility of the forecasting techniques.

In addition to univariate patterns across time, analogies may also be drawn from cross-sectional patterns across multiple variables. In the first instance, time is the patterning dimension for a single variable. In the latter instance, the values of multiple variables are assumed to pattern at discrete moments in time.

The cross-sectional approach has a special attribute. It permits the composite of values of several variables to represent a complex phenomenon. For example, we do not yet have a satisfactory means to detect the onset of a crisis between countries. But we can represent crises known to have occurred in terms of variables which have been measured. That is, we might identify recent crises which have occurred, stipulate all the measurable variables we believe to be of relevance to the crisis, and determine which of these variables have "special" values preceding the crisis in question.

Those variables and values represent a pattern of conditions which can be used to define the precursor analogue of crisis. Future crises, then, may be forecast when similar patterns of conditions are observed currently. A second set of objectives of the present short-term forecasting research is the preliminary development and illustration of this multivariate approach. This research may be considered successful if a unique set of variables and values is generally found to be present in temporal proximity to the crisis cases but rarely in proximity to other cases.

In the previous research, five historical patterns were found in time series of the Relations (R) and Policy Style (S) measures. These patterns were associated with different and statistically significant distribution of the subsequent changes in R and S.

Subjectively, the patterns may be described as follows:

Pattern #1: Time series values fluctuate little and change little from beginning to end. This pattern may be referred to as stable.

Patterns #2 and #4: Time series values have moderate (#2) or high (#4) fluctuation, combined with a significant change in level (D) from beginning to end which proceeds uniformly in direction, i.e., without reversal. These patterns may be referred to as moderate (#2) and major (#4) level changes.

Patterns #3 and #5: Time series values have moderate (#3) or high (#5) fluctuation, which occurs without apparent pattern and with no uniformity in direction. These patterns may be referred to as moderately (#3) or highly (#5) unstable.

TABLE 1
Patterns of Relations and Policy Style

The historical patterns were found by examining three variables:

1. the average fluctuation of all time series values around the most current value (F);
2. the magnitude of the difference between the beginning and most current value (D); and
3. the uniformity in the direction of change, if any, from the beginning to the current value (U).

The five patterns manifest the following characteristics in terms of these three variables:

Pattern	F	D	U
1.	$\leq .10$	$< .2$	not relevant
2.	$> .10 \leq .20$	$\geq .2$	yes
3.	$> .10 \leq .20$	any value	no
4.	$> .20$	$\geq .2$	yes
5.	$> .20$	any value	no

In the experiments involving time series of the Relations measure (R), based on 74 cases (pairs of countries), significantly different distributions of ΔR across the patterns were found. ΔR is the change in the value of R between the end values of the historical time series and a period 24 months later. The values of ΔR were classified as follows:¹

- Low, where $\Delta R \leq +.2$
- Medium, where $\Delta R >+.2 \leq +.4$
- High, where $\Delta R >+.4$

Table 2 presents the ΔR distributions for the 74 cases for each of the five patterns. These distributions are converted to percentages in Table 3.

The percentage distributions in Table 3, are, in effect, probability distributions of future outcomes associated with each pattern. As such, they may, in the absence of other information or in combination with it, be used as the likely outcome distributions for cases which currently conform to each of the historical patterns. That is, we can use these distributions as estimates, or forecasts, of likely changes in Relations over the next two years between country pairs whose past analogue we may calculate empirically.

It is worth noting that the distributions in Table 3 seem intuitively correct in the following ways:

1. Pairs with stable histories of Relations (Pattern #1) are shown to be inclined to remain stable.
2. Pairs whose Relations change moderately in level (Pattern #2) are shown to exhibit a tendency toward stability at the new level; pairs whose Relations change drastically in level (Pattern #4) are also inclined to stabilize at the new level, but there is also a significant tendency to "rebound."

¹ A ΔR value of .2 equals a change of 10% of the R scale, which ranges from +1.0 to -1.0; a ΔR value of .4 equals a change of 20% of the R scale.

TABLE 2
Frequency Distribution of ΔR by Historical Pattern
for 74 Country Pairs

Pattern	Number of Cases	ΔR (24 months)		
		Low	Medium	High
1. Stable	20	14	4	2
2. Moderate level change	9	7	2	0
3. Moderately unstable	17	5	7	5
4. Major level change	14	7	4	3
5. Highly unstable	14	3	4	7
TOTAL	74	36	21	17

TABLE 3
Percentage Distribution of ΔR by Historical Pattern
for 74 Country Pairs

Pattern	Total	ΔR (24 months)		
		Low	Medium	High
1. Stable	100	70	20	10
2. Moderate level change	100	78	22	0
3. Moderately unstable	100	30	40	30
4. Major level change	100	50	29	21
5. Highly unstable	100	21	29	50
TOTAL	100	49	28	23

3. Pairs whose Relations are unstable (Patterns #3 and #5) tend to be the least "predictable"; i.e., for Pattern #3, in particular, the future is almost totally uncertain. Pattern #5, which reflects wide past fluctuations in Relations also shows the greatest tendency toward large future changes.

It should also be noted here that identical patterns and highly similar distributions of subsequent change were found when the experiment was extended to the Policy Style (S) measure. In that experiment, 85 country pair cases were employed.

These results prompted a series of questions which were addressed in the current research on univariate time series analysis. The questions dealt with to date are stated below along with related findings.

How Representative Was the Distribution of ΔR for the Case Sample Employed to Develop the Historical Patterns?

The 74 cases employed in previous experiments with the Relations measure were not randomly chosen. The sample was constrained in two dimensions. First, because of limited time series lengths (1966 through 1972), each country pair contributed only one ΔR value. That is, the historical time series covered the period 1966-1970 and ΔR was measured for 1971 plus 1972; five years of history were employed to make a two-year forecast. Therefore, the sample case reflects changes in Relations for a wide array of country pairs but for just one time period, 1971 plus 1972.

Second, the country pairs employed were limited to pairs of individual countries, for example, the United States and the Soviet Union. Since the Relations measure may be computed for groups of countries as well (for example, United States and the World, or North Atlantic Treaty Organization and Warsaw Pact countries, or all Arab countries), or may be computed within country pairs by subject or issue (for example, Military Relations between the United States and the Soviet Union) the potential sample could have been differently constituted.

In Table 4 the percentage distributions of ΔR across two year periods are recorded for the original sample (Sample 1) and for two additional samples, chosen to test the consistency of the ΔR distribution by eliminating the above sampling constraints. Sample 2 consists of all 24 month changes in R throughout the available time history for the original 74 country pair cases. Sample 3 consists of the ΔR distribution over the original time period (1971 plus 1972) but for a composite of 69 pairs of country groups and issues within country pairs.

The table shows that for 74 country pairs the 1971-1972 ΔR distribution (Sample 1) was almost identical to the distribution across the entire time history (Sample 2). The implication here is that had any sample of time periods for country pairs been chosen randomly, the ΔR distribution would have been similar to that in the original sample employed. On the other hand the ΔR distribution for country pairs and issue pairs (Sample 3) differs somewhat from the others. Specifically, for pairs of this type there seems to be less of a tendency toward high ΔR and more of a tendency toward medium ΔR than in the country pair samples. This finding suggests either that the historical patterns for pairs of these types differ from those for country pairs or that the same patterns yield somewhat different distributions of ΔR for forecasting purposes.

What Are the Historical Patterns and ΔR Distributions for Country Group Pairs and Issue Pairs?

Tables 5 and 6 show the frequency and percentage distributions of ΔR , respectively, for the composite country group and issue sample of 69 pairs. ΔR covers the 1971 plus 1972 time period, the same period employed in the original experiments. By comparing the distributions in Table 6 with those presented earlier in Table 3 the difference between country pairs and country groups may be seen.

It is interesting to note that the ΔR distributions for Pattern 1 are quite similar for both samples. Specifically, cases with a stable history tend to manifest low propensity for change. On the other hand, where a moderate

TABLE 4
Distribution of ΔR for Three Samples

Sample	Percentage Distribution of ΔR			
	Total	Low	Medium	High
1. Original sample 74 country pairs, one time period)	100	49	28	23
2. 74 country pairs, all time periods	100	50	28	22
3. Composite sample of country groups and issues (69 pairs, same one time period as original sample)	100	46	41	13

TABLE 5
Frequency Distribution of ΔR by Historical Pattern
for 69 Country and Issue Pairs

Pattern	Number of Cases	ΔR (24 months)		
		Low	Medium	High
1. Stable	20	12	6	2
2. Moderate level change	6	2	4	0
3. Moderately unstable	15	8	3	4
4. Major level change	11	5	6	0
5. High unstable	17	5	9	3
TOTAL	69	32	28	9

TABLE 6
Percentage Distribution of ΔR by Historical Pattern
for 69 Country Group and Issue Pairs

Pattern	Percentage Distribution of ΔR			
	Total	Low	Medium	High
1. Stable	100	60	30	10
2. Moderate level change	100	33	67	0
3. Moderately unstable	100	53	20	27
4. Major level change	100	45	55	0
5. Highly unstable	100	29	53	18
TOTAL	100	46	41	13

or major level change occurred historically (Patterns 2 and 4) the dominant ensuing change for country group and issue pair cases is a moderate subsequent change in R, whereas in the country pair sample, this pattern had been followed with stability of R near the new level. Finally, the country group-issue pair sample shows less tendency toward high changes in R for cases which were historically unstable (Patterns 3 and 5). These cases, however, like those in the original sample, are less predictable than cases manifesting any other pattern, for example, ΔR is more equally distributed across the low, medium, and high ranges of subsequent values than it is for any other pattern.

The implication of these findings is that while historical patterns may be similarly deduced for different kinds of case samples, the subsequent ΔR distributions may be sufficiently different that their use for forecasting must be restricted to like cases.

How Can the Direction as Well as the Magnitude of Change for R be Forecast?

In previous experimentation with univariate time series, samples have not been sufficiently large to permit isolation of the direction of ΔR by historical pattern. Forecasts based on ΔR distributions, therefore, refer only to magnitudes of likely change.

It seems meaningful to assume that the likely direction of change in R would be associated to some degree with the base of R, for example, that value from which the change is measured. It may be reasoned that since the range of R is scale constrained, for example, R values may range only from +1.0 to -1.0, that at least for high positive and high negative base R values the direction of any change forecast would tend toward lesser values.

Since it would be desirable to test this supposition with the largest possible sample, the distribution of cases by base R values was developed for both Sample 1, the original experimental case sample for country pairs, and for Sample 2, the same country pair cases with extended ΔR coverage (See Table 4). If these two distributions are similar then it is reasonable to use the larger Sample 2 to explore the direction of change.

Table 7 shows the frequency and percentage distributions of base R within the two samples. For this purpose the R scale is divided into five ranges which may be labeled subjectively as follows:

TABLE 7
Frequency and Percentage Distribution of Base R
for Two Case Samples

Base Value of R	SAMPLE 1		SAMPLE 2	
	Frequency	%	Frequency	%
+ .61 to +1.00	7	9	50	8
+ .21 to + .60	23	31	190	30
- .20 to + .20	19	26	144	23
- .60 to - .21	11	15	110	18
-1.00 to - .61	14	19	130	21
TOTAL	74	100	624	100

R =	Country Pair is:
+ .61 to +1.00	mutually supportive
+ .21 to + .60	friendly
- .20 to + .20	neutral
- .60 to - .21	unfriendly
-1.00 to - .61	hostile

In Table 7 it can be seen that the percentage distributions of cases by base R are virtually identical for Samples 1 and 2. Therefore, we may employ Sample 2 to examine direction of change.

For each of the five base R ranges, Table 8 shows the distribution of the 624 cases of Sample 2 by direction of change for low, medium, and high ΔR . For example, the data in the table may be read as follows: of all cases in Sample 2 with base R values between +.61 and +1.00 and with low ΔR values, ΔR was positive in 12 cases and negative in 16 cases. The table illustrates, therefore, the likelihood of positive and negative change for all combinations of base R and ΔR across the entire sample.

For convenience in interpretation, these data are expressed in Table 9 as odds of positive versus negative change for all combinations of base R and ΔR . For example, the data in Table 9 may be read as follows: for any case with a base R value between +.61 and +1.00 and with a low ΔR value, the odds are 1.3 to 1 that ΔR will be negative.

There is an interesting symmetry in Table 9 which bears out our earlier supposition. At all ranges of base R except the neutral range, the odds range from equal (1 to 1) to favoring change away from extreme R values and toward neutrality. Further, the larger is ΔR the more pronounced is this phenomenon. Additionally, however, it should be noted that for neutral values of base R, the derived odds favor positive change for all values of ΔR .

The odds on direction of ΔR in Table 9 may be used in conjunction with the likely magnitudes of ΔR , such as in Table 3, in the following way. Suppose a country pair for which a forecast of ΔR is desired exhibits a Pattern 4 time series history (major level change). According to Table 3, the percentage (probabilistic) distribution of ΔR is:

- Low = 50
- Medium = 29
- High = 21

TABLE 8
Distribution of the Direction and Magnitude of ΔR by
Base Value of R

Base Value of R	Total Cases	ΔR (24 months)					
		Low		Medium		High	
		0 to +.2	0 to -.2	+ .21 to +.40	-.21 to -.40	>+.40	>-.40
+ .61 to +1.00	50	12	16	0	13	0	9
+ .21 to + .60	190	50	50	30	35	5	20
- .20 to + .20	144	28	22	34	13	31	16
- .60 to - .21	110	19	18	18	17	32	6
-1.00 to - .61	130	49	42	15	7	17	0
TOTAL	624	158	148	97	85	85	51

TABLE 9
Odds on the Direction of ΔR by Base Value of R

Base Value of R	ΔR (24 months)					
	Low		Medium		High	
	0 to +.2	0 to -.2	+.21 to +.40	-.21 to -.40	+.40	-.40
+ .61 to +1.00	1	1.3	0	1	0	1
+ .21 to + .60	1	1	1	1.2	1	4
- .20 to + .20	1.3	1	2.6	1	1.9	1
- .60 to - .21	1.1	1	1.1	1	5.3	1
-1.00 to - .61	1.2	1	2.1	1	1	0

Suppose further that the base value of R (in this example, the current value) is +.35. For such a base R value the directional odds for each ΔR range (from Table 9) are:

	<u>Positive</u>	<u>Negative</u>
• Low	1	1
• Medium	1	1.2
• High	1	4

The above two distributions may be combined by applying the directional odds in the second to divide the first between likelihoods of positive and negative changes as follows:

	<u>Positive</u>	<u>Negative</u>
• Low	$(50 \times \frac{1}{2}) = 25$	$(50 \times \frac{1}{2}) = 25$
• Medium	$(29 \times \frac{1}{2.2}) = 13$	$(29 \times \frac{1.2}{2.2}) = 16$
• High	$(21 \times \frac{1}{5}) = 4$	$(21 \times \frac{4}{5}) = 17$

This results in the following forecast distribution for the example case with its base value of +.35.

<u>Forecast distribution</u>	<u>Forecast ΔR range</u>	<u>Likelihood of Change</u>
1. high positive	>+.75	4
2. medium positive	+.55 to +.75	13
3. low positive	+.35 to +.55	25
4. low negative	+.35 to +.15	25
5. medium negative	+.15 to -.05	16
6. high negative	>-.05	17

ONE-MONTH FORECASTING

The research reported above is intended to provide technical assistance in anticipating the general patterns of foreign and international behavior in the two-year future. The field of short-term forecasting is broad enough

to encompass the general two-year focus and a more immediate and specific focus. More immediate and specific forecasting was the subject of research reported in this section.

The more immediate forecasting period was one month. In other words, the techniques developed here could be--and were--used to forecast for the next month in the future. The forecast concept was international crisis. Two alternative measures of crisis were used: 1) a nominal dichotomy, crisis/no crisis; and 2) a richer interval-level crisis measure that reflects degrees of crisis. The latter measure is based on New York Times events and consists of the monthly increase or decrease in threatening and violent events in a dyad.² The historical presence or absence of a crisis is identified from a previous project that compiled a post-World War II inventory of international crises (CACI, 1975).

For each dyad selected, predictive equations were estimated based on past history. Several predictors were formulated and their relationship to past crises was examined. The period covered in these analyses was January 1966 through June 1975. All predictors are event-based and the WEIS New York Times collection was used as the source of events. The unit of analysis was the month.

A large number of potential predictors were considered and examined. These are shown in Table 10. The set of predictors used reflects the general proposition that international behavior patterns in the recent past affect the likelihood of crises in the immediate future. In this regard, both the tone and frequency of current behavior may constrain or drive subsequent developments. The effects of one of these predictors may depend on the condition of the other. For example, the effect of a negative tone may be greater when frequencies are high; hence an interactive (multiplicative)

² The World Event/Interaction Survey (WEIS) coding scheme combined event types included in this measure; Demand, Expel, Reduce, Threaten, Warn Force and Seize.

TABLE 10
Crisis Predictors^a

1. Policy Tone at t-n.^b

The Policy Tone measure is described in CACI, Quantitative Indicators for Defense Analysis (Arlington, Va., 1975)

2. Frequency of action at t-n.

3. The interaction (multiplication) of Tone and Frequency at t-n.

4. The change in Tone from t-(n+1) to t-n.

5. The change in Frequency from t-(n+1) to t-n.

6. The change in the Tone x Frequency interaction from t-(n+1) to t-n.

7. The interaction (multiplication) of variables 1 and 4 at t-n.

8. The interaction (multiplication) of variables 2 and 5 at t-n.

9. The interaction (multiplication) of variables 3 and 6 at t-n.

10. The concentration of activity across categories (H_{rel}) at t-n.

11. The variety of activity at t-n (number of categories in which action occurs).

^a Note that all predictors are bidirectional, for example, encompass the events for both actors in a dyad.

^b Various lags were used: t-1; t-2; and t-3.

predictor. The recent direction of a behavioral relationship also may provide good clues to the immediate future. The effect of a change in behavior, furthermore, may depend on the resultant of the change. For example, a drift toward hostility is less alarming if the actual level of hostility that results is fairly low; hence a number of interactive (multiplicative) predictors involving changes and levels. Two variables measure the dispersion of behavior across categories. Previous studies establish a connection between these concepts and crisis.

Stepwise regression was used to determine which predictors actually contribute significantly to the prediction of crises. Rather than using an F-criterion to determine "significance," a substantive requirement was imposed. The requirement was that, to be included in a predictive equation, a predictor must add at least 5% explained variance when it enters the equation.*

Prediction equations were derived for four dyads: Greece-Turkey, Israel-Syria/Egypt, North Korea-South Korea, and U.S.S.R.-China. Once the best predictive equations for these pairs were determined, actual forecasts were made.

For each dyad, several alternative equations were examined. Lags of one, two and three months were examined for each alternative dependent variable (dichotomy and interval measure). In the case of each dyad, the predictors were found to be most effective at a one-month lag. The predictors were capable of explaining more variance in the interval crisis measure than the dichotomous crisis measure except in the case of Greece-Turkey.

The prediction equations for the four dyads are shown below, along with measures of explained variance. A substantive interpretation for each equation is given. Variables are identified by their numbers in the list in Table 10 above. All predictors are t-1.

* Thus, predictors were required to contribute a set level of partial explained variance regardless of the number of remaining degrees of freedom in the equation.

Greece-Turkey

$$\begin{aligned}\text{Predicted Crisis} &= -.009 - .30\Delta\text{Tone} (\#4) + .88 (\#4 \text{ squared}) + \\ &\quad .24 \text{ relative } \Delta\text{Tone} (\#7) - 1.34 (\#7 \text{ squared}) \\ R^2 &= .49\end{aligned}$$

Crises in Greek-Turkish relations are signalled by a decided deterioration of relations between the two countries--fairly large changes in the negative direction and ending at low tone levels.

Israel-Syria/Egypt

$$\begin{aligned}\text{Predicted Crisis} &= 8.7 + .65 \text{ Tone} \cdot \text{Frequency} (\#3) \\ R^2 &= .30\end{aligned}$$

Crises in Israeli-Arab relations are signalled by high frequency of interaction coupled with a positive or friendly tone in that behavior.

North Korea-South Korea

$$\begin{aligned}\text{Predicted Crisis} &= .73 - .28 \text{ Frequency} (\#2) + .49 \text{ Tone} \cdot \text{Frequency} \\ &\quad \text{Change} (\#6) + .07 \text{ Variable 3} \cdot \text{Variable 6} (\#9) \\ R^2 &= .30\end{aligned}$$

Crises in North Korean-South Korean relations are signalled by low frequencies of interaction coupled with an increase in the friendly tone of relations.

U.S.S.R.-China

$$\begin{aligned}\text{Predicted Crisis} &= .24 - .004 \text{ Variable 2} \cdot \text{Variable 5} (\#8) \\ R^2 &= .38\end{aligned}$$

Crises in Sino-Soviet relations are signalled by large drops in the frequency of interaction between the two countries.

Observations can be made about these equations. First, and perhaps most apparent, is their general failure to account for very large (70% and up) portions of the variance in the crisis variables. The best equation of the four--the one for Greece and Turkey--explains about 50% of the variance. There is a very clear need for continued efforts to enhance explained variance if predictions are desired in which one may place high confidence.

A second and interesting aspect of the equations is that they reflect a tendency for crises to be signalled by very different kinds of phenomena in different dyadic relationships. For example, Greek-Turkish crises are signalled by drops in Tone to unfriendly levels while Arab-Israeli crises are signalled by more friendly Tones; and while Tone is the strong concept in predicting Greece-Turkey crises, frequency is the only effective variable in the Sino-Soviet case. This strongly suggests that a dyad-specific approach to short-term forecasting of this nature can be quite helpful and that the unique characteristics of different dyads contain information useful in forecasting. This is similar to the need for country- and region-specific long-range forecasting equations found in other ARPA-sponsored work (CACI, 1975b).

Two sets of forecasts were made: one set for the month of August, 1975, and the other set for September, 1975. The August forecast was made for two dyads: Greece-Turkey and Israel-Syria/Egypt. The September forecast continued to forecast for these two dyads and added two other pairs: North Korea-South Korea and U.S.S.R.-China.³

The equations described above were used in the forecasting. In the equations, all predictors are measured at $t-1$. Thus, in forecasting the month of August, data for July are used; in forecasting the month of September, data for August are used. In order for forecasts to be timely they should be made prior to the beginning of the forecast periods. To achieve this

³ These efforts are described in greater detail in two papers entitled "Crisis Alert for August 1975," and, "Crisis Alert for September 1975," both prepared by this study team.

timeliness only part of the data for the predictor month (t-1) could be used in the predictions since not all event data could be compiled for a month before the month's end. Thus the first two weeks of data for the predictor month were used and extrapolated (for example, the two-week frequencies were doubled) to represent the entire month.

The forecasts derived in this way were:

August

- Greece-Turkey

A forecast value of .11 on the dichotomous variable is derived. Interpreting this directly as a probability, the likelihood of crisis was high enough to warrant concern. A probability of .11 is higher than 90 percent of the monthly postdictions in the 1966-mid 1975 period.

- Israel-Syria/Egypt

A forecast on the interval measure of 4.4 was derived from an equation later regarded as defective. A different equation--the one shown above--was used in the September forecast. The larger this value becomes, the greater the propensity for crisis. The values of this estimate for the June 1967 crisis and October 1973 crisis were 4.3 and 4.1, respectively. Thus the prediction of 4.4 for September was well within the crisis range, representing a greater than normal likelihood of crisis. As noted above, the equation was found to be defective since the predicted values were arbitrarily constrained to values of 4.5 and below.

September

- Greece-Turkey

A prediction of -.009 on the dichotomous variable was derived. Interpreting this as a probability of zero, the likelihood of crisis in September is as low as it possibly can be.

- Israel-Syria/Egypt

A prediction of 1.52 is derived. This is very well below the actual levels during the two post-1966 Mideast crises of 117 and 175. Thus, it appears, on the basis of the equation, that a September crisis is unlikely.

- North Korea-South Korea

A prediction of .73 for September is derived. Actual North Korea-South Korea relations are more intense than this level at least one-third of the time. Thus, a level of .73 appears to be well below a crisis threshold and the prediction indicates no crisis for September.

- U.S.S.R.-China

For Sino-Soviet relations, a prediction of .23 is derived. This value is well below crisis levels. For example, in actual crises of January 1967 and April 1969 the crisis measure stood at 5 and 3, respectively. Thus the prediction is for no crisis. A measure of caution is required, however, for there is considerable error in the prediction equation. This error is reflected in the fact that the equation postdicts a value less than .23 for January 1967--a period in which a crisis actually occurred.

CONCLUSIONS

Having reviewed the objectives, approach, and findings of this research effort, we step back for a moment to examine its broader implications for the Department of Defense. The effort is part of ongoing ARPA-supported research to identify tools which will enhance the capability of the Department to understand, anticipate, and plan for the policies of foreign governments which impinge upon U.S. defense interests. In a strictly scientific sense, then, identification of tools which appear to be of minimal usefulness to the Department is valuable as identification of potentially very powerful analytic tools.

Moreover, each of these analytic tools can contribute to the formulation of U.S. defense policy to the extent that they reduce the uncertainties facing decision-makers. For example, a particular tool can help Department analysts understand the relevant policies of foreign governments to the extent that it reduces ambiguities in the policy signals that emanate from those foreign countries. More relevant to this particular research effort, a tool can assist analysts to anticipate relevant policies of foreign governments when it reduces uncertainties about the direction and extent of change likely in the countries' policies.

In this context, the short-term forecasting research reported on here produced mixed results. The effort to forecast two-year directions and magnitudes of change in Relations, Style, and other international affairs indicators provided some meaningful reduction of uncertainty for selected classes of country pairs. It was considerably less successful when country groups and issue pairs were used as units of analysis. Thus, it appears that any meaningful reduction of uncertainty achieved by this approach is limited to the gross interactions of nations with one another, at least to the extent that country groups can be viewed as existing to focus on a single or a group of highly similar issues.⁴

⁴ For example, the North Atlantic Treaty Organization can be viewed as a collection of nations for the specific purpose of focusing upon threats from the Soviet Union and her Eastern European allies.

The effort to forecast crises on a monthly basis appears on surface to be less successful. Although any explained variance in the regression equations constitutes some reduction of uncertainty, it seems as though none of the equations produce genuinely meaningful uncertainty reduction, that is, 70-80% or more. There are a number of reasons for the apparently limited utility of these approaches, many of which bear upon the utility of both of these diverse strategies. First, it is clear that international event measures are themselves inadequate bases for forecasting. For one thing, those measures do not constitute data on what is actually occurring in the world, but are filtered by the particular policies of the news source from which they are taken. Other research carried out in conjunction with this effort reveals that different sources can produce much different perceptions of what is actually occurring in the world of international affairs. Moreover, there exists some question regarding the sensitivity of the particular indicators constructed from the raw data. The failure to explain even half of crisis variance for any dyad suggests that the concepts and measures used in conjunction with that effort need to be modified or combined with other levels of analysis to enhance the predictability of the concept of crisis to a point of high confidence.

An example of this type of difficulty appears on the measurement scale for the concept Tone. As presently measured the Tone scale ranges through positive and negative values, positive values representing friendly Tone and negative values representing hostile Tone. This characteristic makes the interpretation of regression coefficients for the Tone predictor quite difficult, and very seriously confounds the interpretation of squared Tone terms. Some rethinking of the Tone concept and operationalization is required for further work in this area.

Second, there is some question as to whether regression analysis is the most appropriate approach to forecasting when these international behavioral measures are the dependent variables. It is important to recognize that regression analysis is based upon variation in the data being analyzed, variation from the mean value of country pair scores for univariate time-series analysis and variation from the mean scores of groups of country

pairs for the cross-sectional analysis. Particularly for very short-term forecasting, it is unclear what substantive meaning can be attached to this kind of variation, and thus it is unclear what substantive meaning can be attributed to the resulting regression coefficients. Much of the disappointment associated with the results of the multiple regression may be attributed to the basic inapplicability of the technique in this particular context.

On the other hand, the probability distribution analyses reported in the two-year forecasting focus appear to offer substantial promise for a range of techniques. Essentially, this approach is a crude version of Markov analysis. Refinement of this kind of approach requires, first, reconceptualizing the data into states or conditions of relations among countries. The presence or absence of crises among nations may be one way of reconceptualizing the data in this manner. Once the conceptualization of the data is consistent with the state or characteristic requirement of Markov analysis, the probabilities developed in the two-year forecasting phase of this effort could be converted into Markov transition matrices, retaining individual matrices for each country pair and/or issue pair as appears appropriate from the analysis. The matrices could then be used to readily represent likely directions and magnitudes of changes in relations among nations over the short term. In this way, at a minimum, the effort reported on here appears to offer substantial promise for reducing uncertainty about the intentions of relevant foreign governments for Department of Defense analysts and planners. The development of one-month Markov tables is a somewhat more expensive, but potentially fruitful approach.

Finally, it is likely that the independent variable set used here, based solely on event data, lacks the richness necessary for highly efficient short-term forecasting. Substantive analysis will argue that coverage from the local press rather than the New York Times would be more likely to detect the first signals of major policy changes before crises occur. This idea is supported by the findings of the Multiple Data Stream portion of research under this contract. Moreover, economic and military variables and their

consistency with the international event variables used here may prove to interact in meaningful crisis prediction sets. Hence, the difficult problem of short-term crisis forecasting will require further efforts, more advanced methodologies and a richer data base before it can succeed.

APPENDIX C

Definition and Measurement of the Relations and Policy Style Indicators

DEFINITION AND MEASUREMENT OF THE RELATIONS AND POLICY STYLE INDICATORS

Relations and Policy Style are indicators of the quality of international interaction. Interaction between a country pair may range from friendly to unfriendly over time, as it consists of a mix of positive, negative and neutral actions. The Relations indicator is defined as the friendly to unfriendly quality of actions flowing between a country pair in both directions (i.e., actions from A to B and actions from B to A). Policy Style is defined as the friendly to unfriendly quality of actions flowing from one country to another (i.e., actions from A to B).

Relations and Policy Style are measured by the particular mix of positive, negative and neutral actions between a pair as reported by the data source. Values of Relations and Policy Style are obtained by the function:

$$R, \text{ or } S = \frac{p - n}{p + n + \frac{ne}{2}}$$

where: R = Relations

S = Policy Style

p = frequency of positive actions reported, in both directions for R, or in one direction for S.

n = frequency of negative actions reported, in both directions for R, or in one direction for S.

ne = frequency of neutral actions reported, in both directions for R, or in one direction for S
(neutral actions are accorded one-half weight in measuring R and S).

The values of this function range from +1.0 to -1.0. A plus value of R or S indicates that positive actions exceed negative actions, and therefore, that R or S is friendly; a minus value of R or S indicates the opposite. The magnitude of the plus or minus values of R or S indicates the degree to which Relations or Policy Style are positive or negative, respectively (i.e., how friendly or how unfriendly).

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