N92-24330

A CASE OF POOR SUBSTRUCTURE DIAGNOSTICS

Thomas G. Butler

BUTLER ANALYSES

Substructuring is a powerful tool. As with any powerful tool the options for managing a job are legion. On the other hand, the NASTRAN Manuals in the Substructuring area are all geared toward instant success, but the solution paths are fraught with many traps for human error. Thus, the probability of suffering a fatal abort is high. In such circumstances, the necessity for diagnostics that are user friendly is paramount. This paper is written in the spirit of improving the diagnostics as well as the documentation in one area where the author felt he was backed into a blind corner as a result of his having committed a data oversight. This topic will be aired by referring to an analysis of a particular structure.

The structure, under discussion, used a number of local coordinate systems that simplified the preparation of input data. The principal features of this problem are introduced by reference to a series of figures.

Figure 1 illustrates a **PILOT** model of the basic component substructure of a full scale structure. This pilot model was used to explore the error that developed in the true structure. In preparation for the investigation into the difficulty that was encountered during a "COMBINE" operation, the pilot basic was cloned 4 times into CLONA, CLONB, CLONC

and CLOND.

Figure 2 tabulates the bulk data for the 5 coordinate systems that were used in the basic component. Coordinate system "5" is cylindrical and was used for its core. Coordinate systems "50, 60, 70 & 80" are rectangular and were used for the four arms with their local X axes pointing outward at zero degrees, 90, 180 and 270 respectively. Each clone retained its own copy of the set of five local coordinate systems. Thus, the Substructure Operating File (SOF) at this point had a complement of 5 x 5 = 25 coordinate systems to catalog. The multiplicity of coordinate systems was at the root of the fatal error which erupted.

Figure 3 illustrates two separate "COMBINE" operations amongst the substructures. In the first "COMBINE", point 51 of P/S CLONC joins with point 71 of P/S CLOND. In the second "COMBINE", point 61 of P/S[1] BASE joins with point 81 of P/S CLONA, while point 61 of P/S CLONA joins with point 81 of P/S CLONB.

During the subsequent linking of substructures, the points that were combined each had their own local coordinate systems. Well this doesn't seem to be a problem, because NASTRAN has a wonderful module called CSTM (Coordinate System Transformation Matrix) which keeps track of all transformations amongst a host of coordinate systems. So the user is disarmed into thinking that

---

1. The abbreviation P/S, meaning pseudo-structure, is used as a generic term for any number of different kinds of substructures: basic, or clones, or condensations, or combined.

NASTRAN can handle anything dealing with coordinates. This was especially true in this case, because, just prior to the abort being described here, a mistake in translating one of the cloned structures was corrected in response to a diagnostic message that declared that points, which were targeted to be joined, were not within tolerance. The error was that one of the translations, defined on a "TRANS" card was off by an eighth of an inch. After the correction a message was issued declaring that all points in the "COMBINE" operation were within tolerance. So the reaction to a subsequent message to the effect that the local coordinate systems were incompatible seemed ridiculous, because NASTRAN had no difficulty in locating the points in space and in pronouncing that they were within tolerance with the coordinate systems that were corrected.

As it turned out there are a number of different coordinate systmes that have to be dealt with here, and the "TRANS" set that was just corrected - though at first suspected - was not at the nub of the problem. The problem arises not in the alignment, which the TRANS coordinates deal with, but in the subsequent mating, which depends of the local DISPLACEMENT coordinates of points that are being brought together.

As a matter of general substructuring principle, when a group of substructures is assembled, any place where parts are linked can involve contributions from 2 or more individuals. At any such place the set of points are merged into a resultant single point. What is not told in the manuals is that the resultant point needs to refer to just one coordinate system. If all of the merging points refer to a common coordinate system, there is no problem. But, when each point has its own local displacement coordinate system, NASTRAN aborts and issues a message #6528

saying that incompatible local coordinate systems have been found. But if the user thinks that the problem has just been corrected, the characterization of the coordinates in message #6528 as being "incompatible" doesn't make sense and he becomes convinced that there must be a bug in NASTRAN and the user is to be absolved of blame. His certitude of blamelessness is further reenforced by the details that are supplied with the diagnostic message. The text of the complete message, shown in Figure 4, refers to local coordinate systems 1 and 10. But if you look at Figure 2, you can verify that no coordinate system was numbered 1 or 10. This seems to further corroborate that NASTRAN got some tables mixed up and is in need of having a bug straightened out.

Gordon Chan of the UNISYS Support Group came to my rescue and published the transformation matrices for the coordinate systems that were involved. The reason that NASTRAN aborted was not because of an error in the code. It deliberately compared the local coordinates at the combining point and found that one pair of signs was aligned while the signs of two other axes were of opposite in sign. The message referring to coordinate systems resulted from a partially completed execution of the COMBINE command. It had reassinged coordinate system ID's in terms of its own internal bookkeeping system, but it phrased the diagnostic in terms of its own scheme of ID's. Unformtunately, that part of its completed operation was never output, because of the abortion, so the diagnostic which was trying to be helpful was confusing the situation even further. However, NASTRAN appeared to be operating properly.

Double checking of coordinate systems 50 through 80 found them to be error free. As a further check, the manual method was

compared to the automatic method of combining. The same diagnostic regarding incompatible local coordinates showed up in this automatic trial as well, but this time referred to pairs of coordinates with other sets of strange identifications; i.e. 2 & 9 and 7 & 14. That diagnostic is shown in Figure 5. Finally a vague, misty fragment seemed to kindle in the back of my brain that had something to do with the data card called "GTRAN". I pored over the Substructure Section of Chapter 1 of the User's Manual to uncover a hint on the use of GTRAN. No help. Nor was the Theoretical Manual any assistance. Figure 1 shows that in the example of the manual COMBINE, points 51 and 71 refer to coordinate systems 50 & 70 respectively. NASTRAN finds that these two systems do not align with each other and so both cannot be allowed to represent that point after a merge. The situation must be reconciled and NASTRAN needs guidance from the user. The avenue by which the user exerts his preference is through the use of GTRAN. The bulk data explanation of GTRAN left many unanswered questions. The only thing left to do was to resort to the old "black box" method of finding out how it behaved. GTRAN was tried out under its options. One option is to refer all connecting points to the overall basic system, and the other is to refer them to the system defined by the TRANS entry. Both worked! Figure 6 shows an excerpt of the output from a successful manual run using GTRAN. It repeats the message about points within tolerance, then gives the tabulation of the resulting points after the COMBINE operation, showing those degrees of freedom that were merged into a single point. This connectivity summary does not, however, refer to any coordinate system. Coordinate ID information is published subsequently in the BGSS. In this case the BGSS shows that it was arbitrated by referring both points to the "0" system (the overall basic).

Figure 7 is an excerpt of a summary of connectivities for the automatic COMBINE case after a proper use of GTRAN. It shows a similar set of connections as in the manual case but amongst BASE, CLONA, and CLONB.

There were many unhappy features relating to documentation in this encounter: (1) the diagnostic itself, (2) the explanation of the diagnostic in Chapter 6, (3) the guide to modeling in Chapter 1, (4) the explanatory notes in the bulk data, and (5) the Theoretical Manual. It is incumbent upon the manuals to acquaint the user with what _its_ needs are so that he can supply necessary data. But in this instance the documentation gave NO hint of how NASTRAN operated internally, so the user was set adrift by a diagnostic that impugns his data as INCOMPAT-IBLE. For all he knew NASTRAN had some sort of internal default to meet the arbitration needs. Without the help of documentation, the user must look into the code to find out what NASTRAN is doing in subroutine "COMB1". He does not know from the above documentary sources whether NASTRAN takes a default when not supplied with specific direction or aborts. The situation is this. NASTRAN first determines that the points that it is directed to link are collocated. This can be done by temporarily transforming all locations to the overall basic system. But now when it wants to trim all connecting points to a single point, it must assign some coordinate system to that resulting point. But which one? Dave Herting and the savants that helped him with the architecture of SUBSTRUCTURING were aware of the problem and provided for it with the GTRAN card. But as is often the case with programming, the documentation did not coach the user into anticipating the need to guide NASTRAN in the assignment of a coordinate system to a common point.

Rather than overcome the obstacle with the provision of a GTRAN card and then to continue with the analysis of the structure only, I chose to share this experience at the Colloquium and to volunteer a supplement to the documentation so that any subsequent user can be well guided when he encounters message #6528. Figure 8 shows the recommended diagnostic message. Figure 9 shows the recommended supplement to the "COMBINE" section of Chapter 1 on modeling with substructures, and in Chapter 6 on explanation of diagnostics. No suggestions are offered for the Theoretical Manual, because it is currently awaiting a major revision.

I extend my deep appreciation to Gordon Chan for his help in unearthing this problem and for his modification of the diagnostic message in the code. The new release will have the revised diagnostic message. In addition Gordon Chan added a printout of the transformation matrices of the coordinate systems that are indicted.

My hope is that this small effort will save future users much time and frustration when faced with an unsuccessful COMBINE operation in their substructuring work.
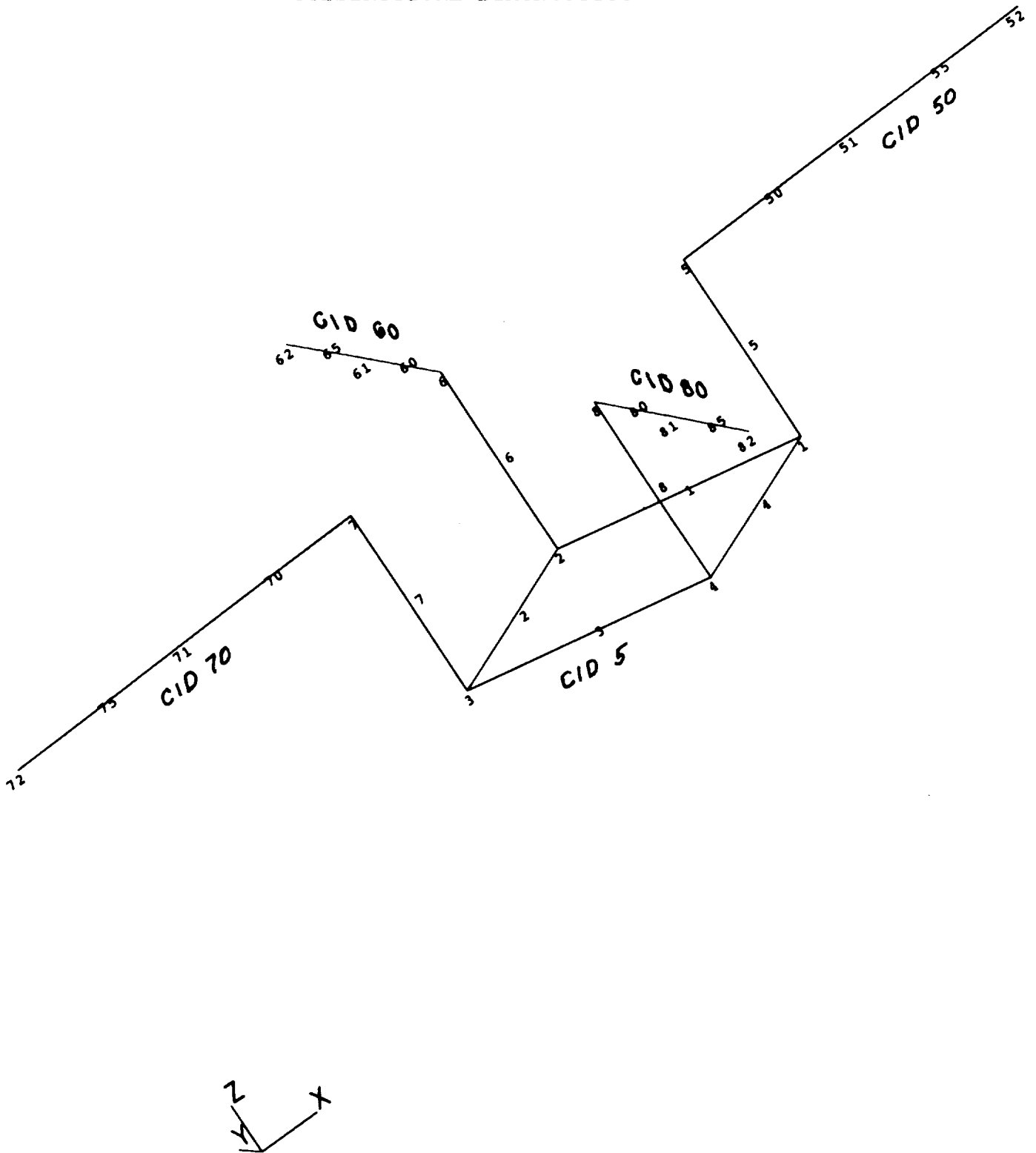
Figure 1. Plot of Basic Component BASE of Pilot Model.

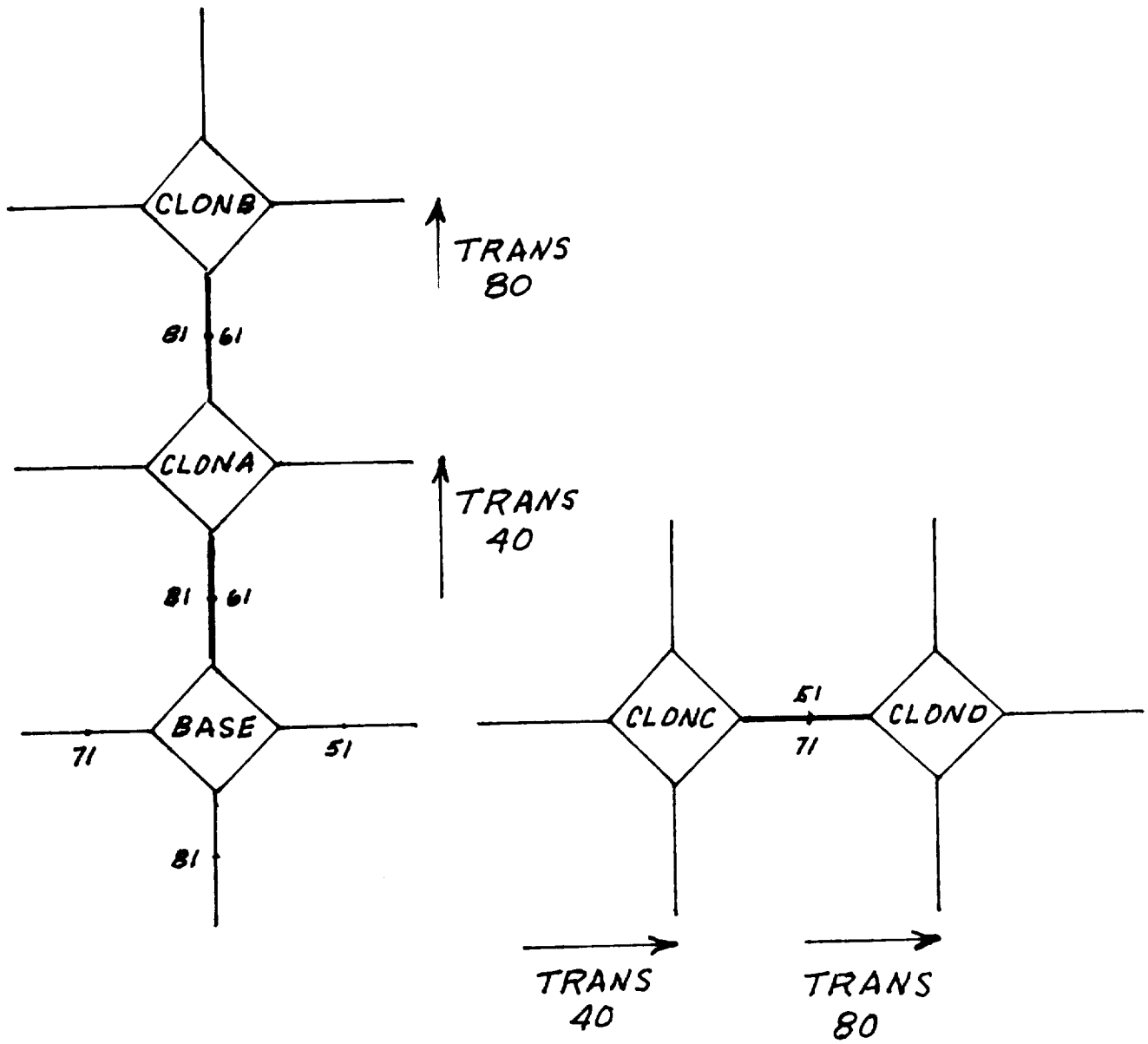| CORD2C	5	0	0.0	0.0	0.0	0.0	0.0	10.0	+CYLN
+CYLN	10.0	0.0	10.0						
CORD2R	50	0	10.0	0.0	10.0	10.0	-10.0	10.0	+RAY0
+RAY0	20.0	-10.0	10.0						
CORD2R	60	0	0.0	10.0	10.0	10.0	10.0	10.0	+RAY90
+RAY90	10.0	20.0	10.0						
CORD2R	70	0	-10.0	0.0	10.0	-10.0	10.0	10.0	+RAY18
+RAY180	-20.0	10.0	10.0						
CORD2R	80	0	0.0	-10.0	10.0	-10.0	-10.0	10.0	+RAY27
+RAY270	-10.0	-20.0	10.0						

Figure 2. Coordinate Systems in Component BASE

Figure 3. Connection Diagram of Two COMBINE Operations

USER INFORMATION MESSAGE 6516,
ALL MANUAL CONNECTIONS SPECIFIED ARE
ALLOWABLE WITH RESPECT TO TOLER.

USER FATAL MESSAGE 6528,
INCOMPATABLE LOCAL COORDINATE SYSTEMS
HAVE BEEN FOUND. CONNECTION OF POINTS
IS IMPOSSIBLE, SUMMARY FOLLOWS.

****

THE FOLLOWING MISMATCHED LOCAL COORDINATE
SYSTEMS (CSTM) HAVE BEEN FOUND FOR

LOCAL COORDINATE SYSTEM ID NO.   1
PSEUDOSTRUCTURE ID NO.   1
INTERNAL POINT NO.   2

****
          LOCAL COORDINATE SYSTEM ID NO.   10
          PSEUDOSTRUCTURE ID NO.   2
          INTERNAL POINT NO.   14

 USER FATAL MESSAGE 6537, MODULE COMB1
TERMINATING DUE TO ABOVE ERRORS.

Figure 4. Diagnostic From Abort of Manual COMBINE

SUMMARY OF AUTOMATICALLY GENERATED CONNECTIONS

CONNECTED DOF	CONNECTION CODE	PSEUDOSTRUCTURE NAMES		
		BASE	CLONA	CLONB
123456	12	7	15	0
123456	12	5	13	0
123456	12	3	11	0
123456	23	0	7	15
123456	23	0	5	13
123456	23	0	3	11

USER FATAL MESSAGE 6528,
INCOMPATABLE LOCAL COORDINATE SYSTEMS
HAVE BEEN FOUND. CONNECTION OF POINTS
IS IMPOSSIBLE, SUMMARY FOLLOWS.

****

THE FOLLOWING MISMATCHED LOCAL COORDINATE
SYSTEMS (CSTM) HAVE BEEN FOUND FOR

LOCAL COORDINATE SYSTEM ID NO.   2
PSEUDOSTRUCTURE ID NO.   1
INTERNAL POINT NO.   5

****

        LOCAL COORDINATE SYSTEM ID NO.   9
        PSEUDOSTRUCTURE ID NO.   2
        INTERNAL POINT NO.   13

****

THE FOLLOWING MISMATCHED LOCAL COORDINATE
SYSTEMS (CSTM) HAVE BEEN FOUND FOR

LOCAL COORDINATE SYSTEM ID NO.   7
PSEUDOSTRUCTURE ID NO.   2
INTERNAL POINT NO.   5

****

        LOCAL COORDINATE SYSTEM ID NO.   14
        PSEUDOSTRUCTURE ID NO.   3
        INTERNAL POINT NO.   13

USER FATAL MESSAGE 6537, MODULE COMB1
TERMINATING DUE TO ABOVE ERRORS.

Figure 5. Diagnostic From Abort of Automatic COMBINE

USER INFORMATION MESSAGE 6516,
ALL MANUAL CONNECTIONS SPECIFIED ARE
ALLOWABLE WITH RESPECT TO TOLER.

SUMMARY OF PSEUDOSTRUCTURE CONNECTIVITIES

INTERNAL POINT NO	INTERNAL DOF NO	DEGREES OF FREEDOM	PSEUDOSTRUCTURE NAMES CLONC	CLOND
–	–	–	–	
16	89	123456	CLONC 72	
17	95	13	CLONC 51	CLOND 71
18	97	123456		CLOND 51
–	–	–	–	

Figure 6

Summary of Connectivities After GTRAN Use in Manual COMBINE

SUMMARY OF AUTOMATICALLY GENERATED CONNECTIONS

CONNECTED DOF	CONNECTION CODE	PSEUDOSTRUCTURE NAMES		
		BASE	CLONA	CLONB
123456	12	7	15	0
123456	12	5	13	0
123456	12	3	11	0
123456	23	0	7	15
123456	23	0	5	13
123456	23	0	3	11

SUMMARY OF PSEUDOSTRUCTURE CONNECTIVITIES

INTERNAL POINT NO	INTERNAL DOF NO	DEGREES OF FREEDOM	$\star$ PSEUDOSTRUCTURE NAMES		
			BASE	CLONA	CLONB
-	-	-	-		
16	89	123456	BASE 72		
17	95	13	BASE 61	CLONA 81	
18	97	123456		CLONA 52	
-	-	-	-	-	
33	183	123456		CLONA 2	
34	189	13		CLONA 61	CLONB 81
35	191	123456			CLONB 52
-	-	-		-	

Figure 7

Summary of Connectivities After GTRAN Use in Automatic COMBINE

USER FATAL MESSAGE 6528

INCOMPATABLE LOCAL COORDINATE SYSTEMS HAVE BEEN FOUND. COMPLETTION OF
CONNECTION IS IMPOSSIBLE. SUGGEST USE OF "GTRAN". SUMMARY IN TERMS OF
JUST-FORMED INTERNAL FREEDOMS AND INTERNAL COORDINATE SYSTEM ID'S PER THE
EQSS & BGSS FOLLOW: ------------

Figure 8.   Revised Fatal Diagnostic Message 6528

USER'S MANUAL CHAPTER 1.

ADD THE FOLLOWING TEXT TO SUPPLEMENT THE TOPIC OF THE "COMBINE" OPERATION ON SUBSTRUCTURING IN THE NASTRAN USER'S MANUAL, PAGE 1.10-39 (14 LINES UP FROM THE BOTTOM OF THE PAGE.

WHEN POINTS ARE ALIGNED FOR COMBINING AFTER A TRANSLATION AND/OR ROTATION OF COMPONENTS, THEY BECOME A SINGLE POINT UPON LINKING. IF THE POINTS ABOUT TO BE CONNECTED REFER TO DIFFERENT LOCAL COORDINATE SYSTEMS, THE SUBSTRUCTURE ROUTINE "COMB1" DOES NOT IMPOSE A DEFAULT CORRDINATE SYSTEM FOR THE POINT. SUCH A SITUATION MUST BE ANTICIPATED BY THE ANALYST TO AVOID A FATAL ABORTION. THE ANALYST CAN ASSIGN A DISPLACEMENT COORDIANTE SYSTEM TO THE RESULTING POINT THROUGH THE USE OF THE GTRAN CARD. IT OFFERS 3 OPTIONS: (1) TRANSFORM TO THE OVERALL BASIC SYSTEM, (2) NO TRANSFORMATION, AND (3) TRANSFORM TO THE COORDI- NATE SYSTEM WHICH WAS DEFINED ON THE SELECTED "TRANS" CARD.

USER'S MANUAL CHAPTER 6.

ADD THE FOLLOWING TEXT AFTER THE FIRST SENTENCE OF DIAGNOSTIC MESSAGE 6528.

EACH POINT IS CARRYING ITS OWN LOCAL COORDINATE SYSTEM INTO THE "COMBINE'D" POINT AND THEY HAVE BEEN FOUND TO BE DIFFERENTLY ALIGNED; I.E. INCOMPATABLE. THE USER IS REQUIRED TO ARBITRATE BETWEEN THE COMPETING LOCAL COORDINATE SYSTEMS. HE IS ADVISED TO CONSIDER USING ONE/OR SEVERAL "GTRAN" CARDS. (SEE PAGE 1.10-39 OF THE USER'S MANUAL.) HE IS FURTHER ADVISED TO "DESTROY" THE PSEUDO-STRUCTURE DEFINED IN THE COMBINE OPERATION IN ORDER TO REMOVE ANY PARTIALLY COMPLETED "COMBINE" DATA FROM THE SOF (SUBSTRUCTURE OPERATING FILE), BEFORE RERUNNING THE "COMBINE" OPERATION.

Figure 9. Supplements to Documents in USER'S Manual