NASA/CR-2001-210834

Preprocessing for Eddy Dissipation Rate and TKE Profile Generation

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March 2001

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National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-2199

Prepared for Langley Research Center
under Contract NAS1-96014

March 2001

Available from:

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7121 Standard Drive
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1.0 Introduction

NASA Langley Research Center has been developing and testing the Aircraft VOrtex Spacing System (AVOSS), a set of algorithms, sensor systems and models to assess the behavior of aircraft wakes near the terminal area and to provide safe wake vortex spacing criteria (ref. 1). AVOSS requires some measure of ambient atmospheric turbulence in order to determine important wake characteristics. Two common measures of atmospheric turbulence, eddy dissipation rate (EDR) and turbulent kinetic energy (TKE), were chosen as candidate input parameters. Vertical profiles up to 600 meters are needed. Measurements can only be routinely provided near the surface. Therefore, NASA sponsored the development of the Atmospheric Turbulence Profile Generator (ATPG). North Carolina State University produced software modified by North West Research Associates that generated atmospheric boundary layer turbulence profiles based on classic Similarity Theory (ref. 2). Winds, temperatures, and turbulence measurements at two levels near the ground are the only input requirements. The original modified code was developed and used in a research environment where input parameters could be screened and chosen to ensure validity. Since it was necessary to use this software in a real-time environment with actual measurements of winds, temperatures, and turbulence from an instrumented 43-meter tower, a preprocessor was developed. Real-time data can introduce bad values or crash the program. The strategy was to preprocess inputs in order to provide reasonable data for missing values or for invalid input based on quality assurance criteria. This allowed AVOSS to provide safe spacing during periods of low confidence data.

The purpose of the preprocessor is to check the input parameters to the turbulence profile code to ensure that they are within reasonable ranges and to provide alternatives when necessary.

2.0 Error Check Criteria

Table 1 lists all input parameters needed to generate turbulence profiles and ranges within which the data are expected to fall. Virtual potential temperatures and wind speeds are needed from both the 3 and 10 meter level. In order to tie the theoretical profiles to actual measurements, eddy dissipation and TKE are calculated from fluxpak measurements at altitudes of 5 meters and 43 meters. Missing data due to a sensor malfunction or communications failure at any level, are reported as 9999 and are not allowed to be passed to the ATPG code. The values for the other parameters are based on past measurements and a reasonable expectation of what would constitute a legitimate value for the Dallas-Fort Worth airport where the measurements are obtained. A 43-meter tower provides the platform for all input parameters: wind speeds, temperatures, eddy dissipation and TKE. Thirty-minute averages are used so that a single one-second measurement for the winds and temperatures or the 10 samples per second TKE or EDR would have little affect on the average value. If any of the input measurements fall outside the range (or are missing), then values are filled in or a "canned" profile based on a neutral atmosphere is generated in accordance with a set of rules discussed below and schematically depicted in Figure 1.

Table 1: Input Parameters and Valid Ranges

Parameter Name	Description	Range
THLO	Virtual temperature at 3 meters (K)	At least 263 but not greater than 318
THHI	Virtual temperature at 10 meters (K)	At least 263 but not greater than 318
WSLO	Wind speed at 3 meters (m/s)	At least 0 but not greater than 40
WSHI	Wind speed at 10 meters (m/s)	At least 0 but not greater than 50
TKE5	TKE at 5 meters (m^2/s^2)	At least 0 but not greater than 10
TKE40	TKE at 40 meters (m^2/s^2)	At least 0 but not greater than 10
EDR5	EDR at 5 meters (m^2/s^3)	At least 0 but not greater than 1
EDR40	EDR at 40 meters (m^2/s^3)	At least 0 but not greater than 1

3.0 Data fill-in Procedures and Effects

The logic implemented for the preprocessor is shown in the flow chart in Figure 1. If either the 3- or 10-meter temperature or wind speed is out of range, the other is used as a legitimate substitute. The arbitrary substitution for temperatures forces profiles characteristic of a near-neutral atmosphere. It also exaggerates the stability or instability in the case of no wind speed shear. Both resultant profiles, however, are considered more reasonable than one that would be totally arbitrary. If either TKE or EDR at just one measurement level is missing, the measurement at the other level is used as a fill in. This substitution has little effect on profiles above the tower (43 meters). If temperatures or winds at both 3 and 10 meters are missing, and valid TKE and EDR measurements are available, then the EDR and TKE observed is assumed to be constant with altitude. In that case, a larger value of turbulence would be provided above the tower than similarity theory would predict in all but neutral or very unstable atmospheres. Once again, however, it is assumed to be more representative than an arbitrary profile. If both levels of TKE or EDR are out of range, then profiles will continue to be generated from the measurements from up to three previous time periods. Because a nominal AVOSS data-run is expected every half hour, data up to, but not including, two hours old could be used to generate the profiles. Finally, if there is no valid EDR or TKE at either tower level for two hours or longer, an arbitrary neutral atmosphere TKE and EDR profile is provided.

4.0 Flags

Flags are set to indicate each of the data fill-ins and substitute profiles discussed above. The flags are used by AVOSS to screen low quality data. The seven flags used and their triggers are shown in Table 2. Flags 1 through 4 indicate when any single level EDR or TKE is missing and was filled-in with the measurement from the other tower level. Flag 5 indicates the use of old data (up to three periods) to generate the profiles. Flag 6 indicates the use of constant profiles when temperatures or winds at both levels are missing. Flag 7 indicates use of a default profile generated from a neutral atmosphere.

Table 2: QA Flags

Flag Number	Meaning
1	1 if the 5 meter fluxpac TKE or EDR is out of range
2	1 if the 40 meter fluxpac TKE or EDR is out of range
3	1 if the 3 meter savpac wind or temperature is out of range
4	1 if the 10 meter savpac wind or temperature is out of range
5	1 if the last valid profile is being returned. (less than 2 hours old)
6	1 if returning a constant profile based on TKE and EDR input
7	1 if returning a default (canned) profile

5.0 Summary and Conclusions

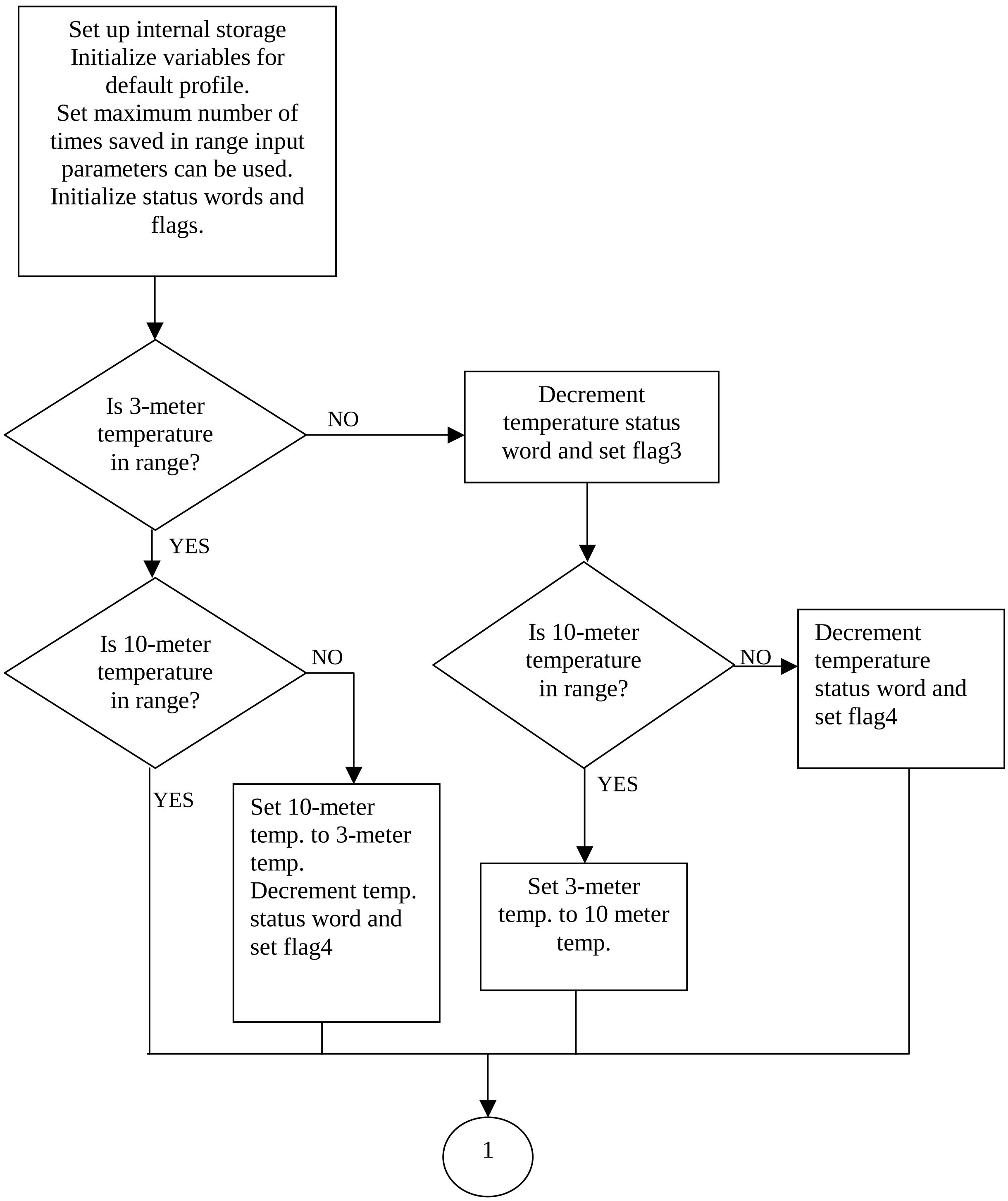
Since AVOSS requires turbulence profiles to appropriately determine aircraft spacing, turbulence profiles must always be produced, even if the result is an arbitrary (canned) profile. The original turbulence profile code was generated and used in a non-real-time environment in the past. All of the input parameters could be carefully selected and screened prior to input. Since this code must run in real-time using actual measurements in the field as input, the field measurements must be checked and screened as part of the real-time implementation. The process described herein is a step towards ensuring that only reasonable input data will be passed to the ATPG code and thus provide the best possible turbulence profiles for AVOSS. Data fill-ins, constant profiles, and default profiles are used only as a last resort, but are essential to ensure automated execution of AVOSS.

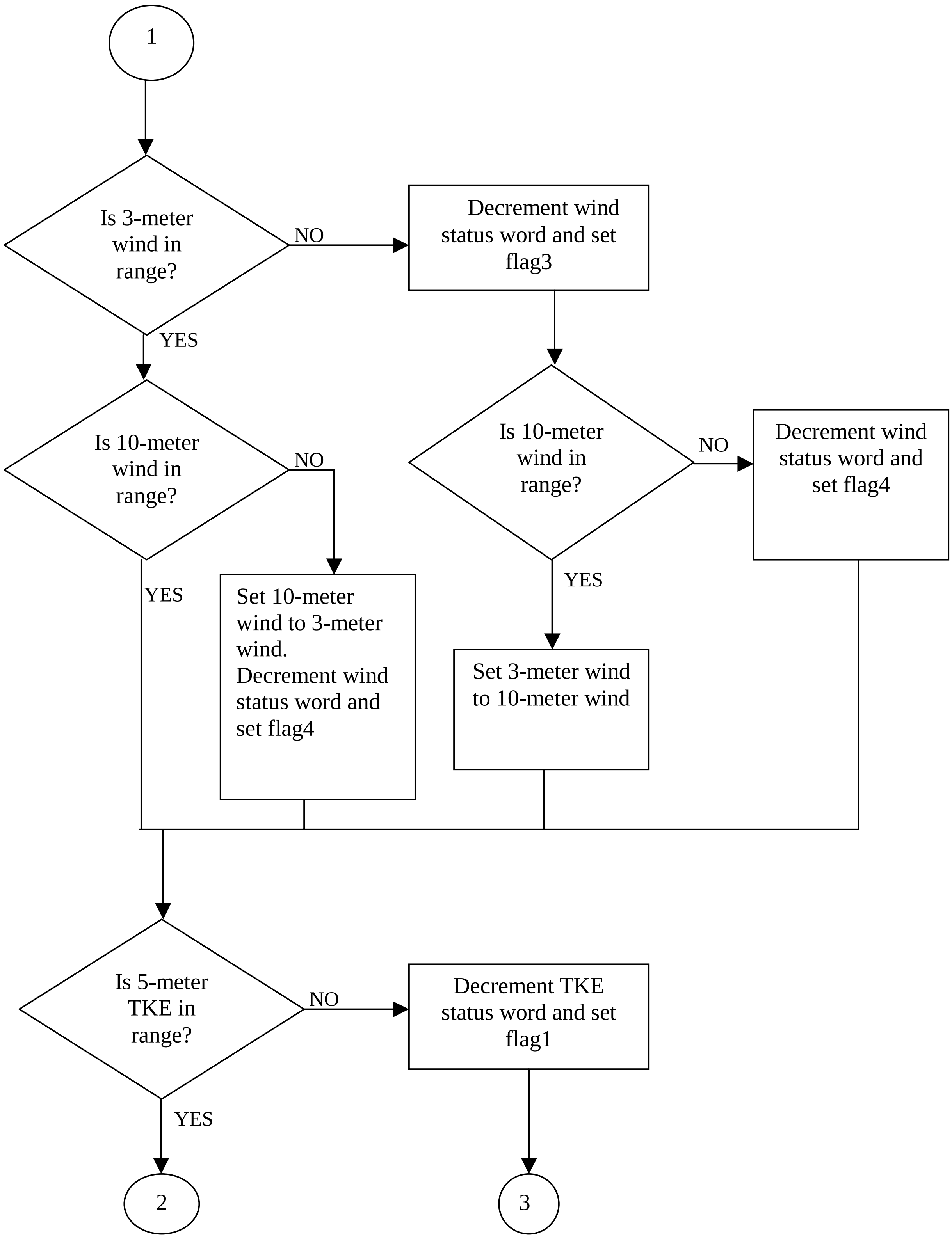
References

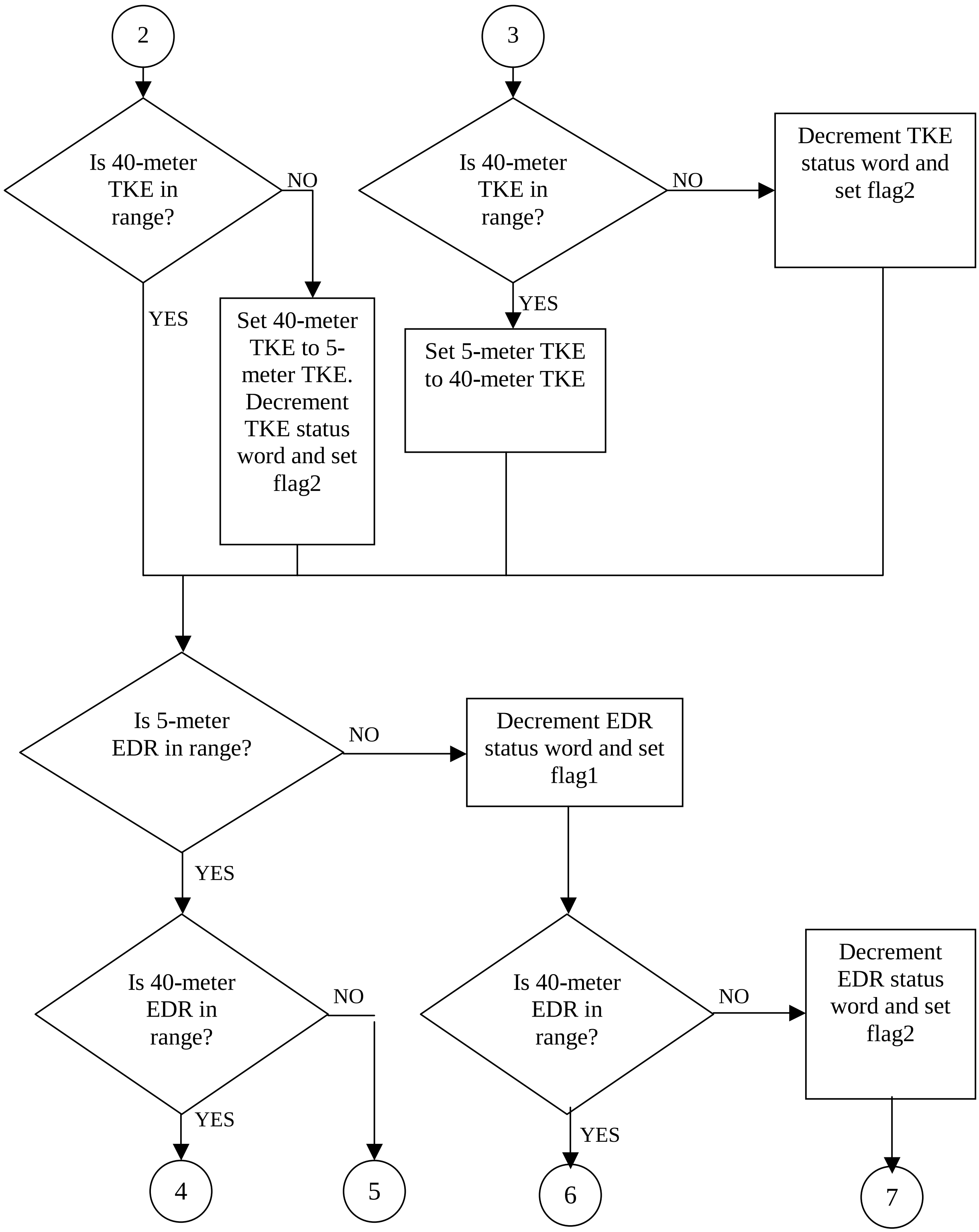
1. Hinton, D. A., 1995, "Aircraft Vortex Spacing System (AVOSS) Conceptual Design", NASA Technical Memorandum 110184, NASA Langley Research Center, Hampton, VA.

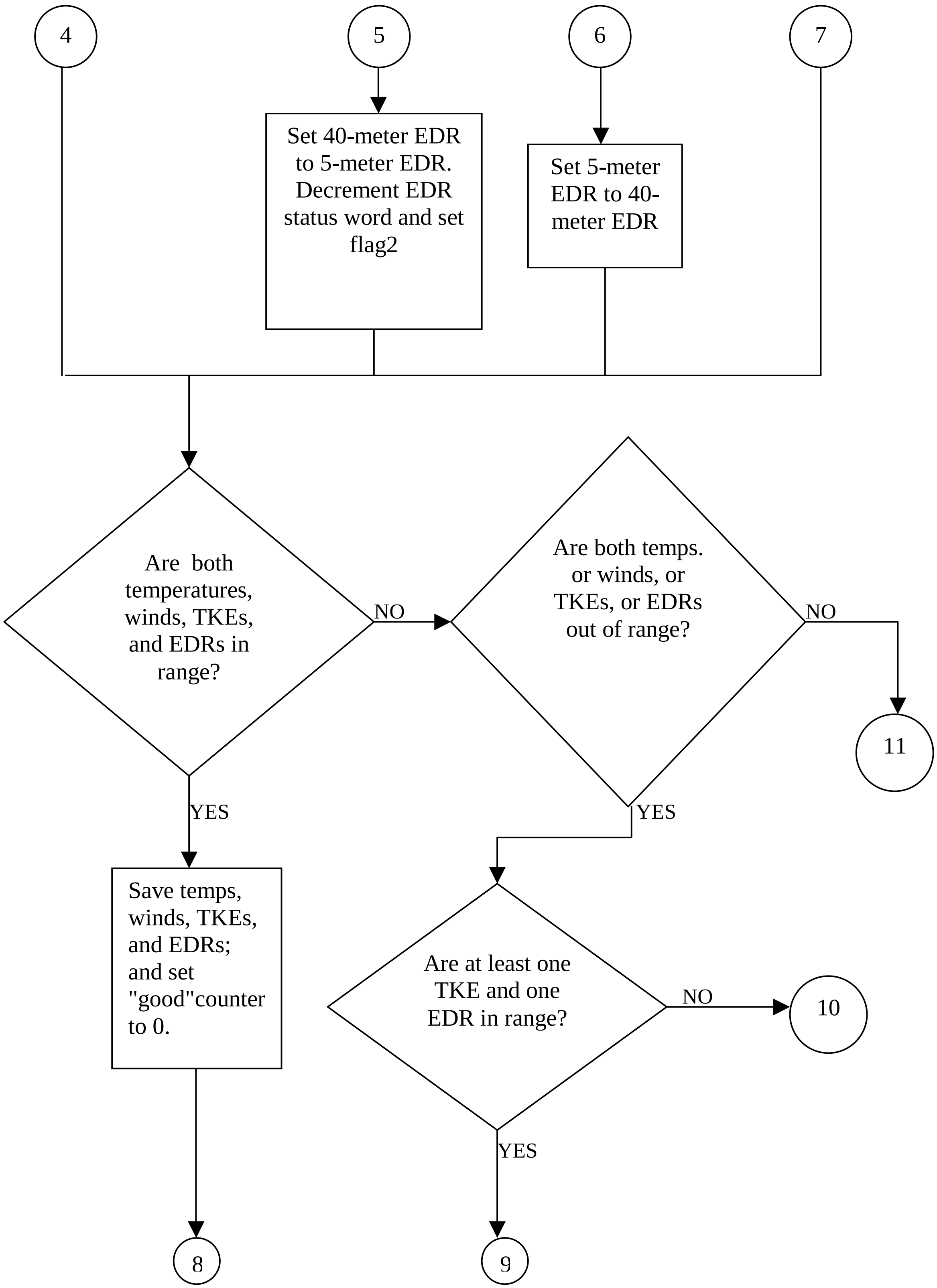
2. Han, J., Shen, S. P., Arya, and Lin, Y. L., 2000, "An Estimation of Turbulent Kinetic Energy and Energy Dissipation Rate Based on Atmospheric Boundary Layer Similarity Theory", NASA/CR-2000-210298, June 2000.

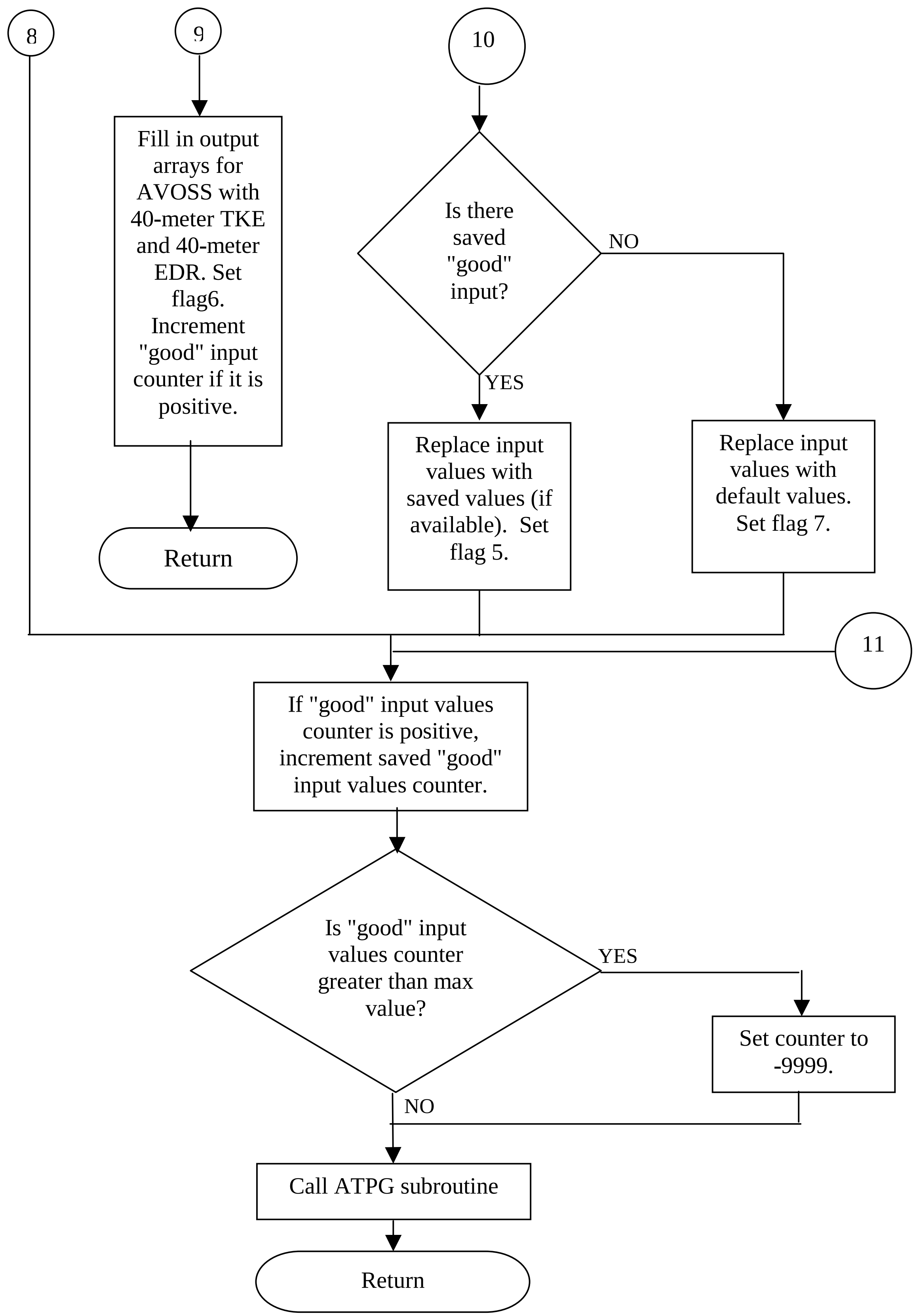
Figure 1: Flow chart of PREATG subroutine.




1
Is 3-meter wind in range?
NO
Decrement wind status word and set flag3
YES
Is 10-meter wind in range?
NO
Is 10-meter wind in range?
NO
Decrement wind status word and set flag4
YES
YES
Set 10-meter wind to 3-meter wind. Decrement wind status word and set flag4
Set 3-meter wind to 10-meter wind
Is 5-meter TKE in range?
NO
Decrement TKE status word and set flag1
YES
2
3


2
3
Is 40-meter TKE in range?
NO
YES
Set 40-meter TKE to 5-meter TKE. Decrement TKE status word and set flag2
Is 40-meter TKE in range?
NO
Decrement TKE status word and set flag2
YES
Set 5-meter TKE to 40-meter TKE
Is 5-meter EDR in range?
NO
Decrement EDR status word and set flag1
YES
Is 40-meter EDR in range?
NO
YES
Is 40-meter EDR in range?
NO
Decrement EDR status word and set flag2
YES
4
5
6
7


4
5
6
7
Set 40-meter EDR to 5-meter EDR. Decrement EDR status word and set flag2
Set 5-meter EDR to 40-meter EDR
Are both temperatures, winds, TKEs, and EDRs in range?
NO
Are both temps. or winds, or TKEs, or EDRs out of range?
NO
11
YES
YES
Save temps, winds, TKEs, and EDRs; and set "good"counter to 0.
Are at least one TKE and one EDR in range?
NO
10
YES
8
9


8
9
10
Fill in output arrays for AVOSS with 40-meter TKE and 40-meter EDR. Set flag6. Increment "good" input counter if it is positive.
Return
Is there saved "good" input?
NO
YES
Replace input values with saved values (if available). Set flag 5.
Replace input values with default values. Set flag 7.
11
If "good" input values counter is positive, increment saved "good" input values counter.
Is "good" input values counter greater than max value?
YES
Set counter to -9999.
NO
Call ATPG subroutine
Return

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
March 2001

3. REPORT TYPE AND DATES COVERED
Contractor Report

4. TITLE AND SUBTITLE
Preprocessing for Eddy Dissipation Rate and TKE Profile Generation

5. FUNDING NUMBERS
C NAS1-96014

WU 728-40-30-01

6. AUTHOR(S)
J. Allen Zak and William G. Rodgers, Jr

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Vigyan, Inc., Hampton, VA 23666
and
Lockheed Martin, Hampton, VA 23681

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Langley Research Center
Hampton, VA 23681-2199

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA/CR-2001-210834

11. SUPPLEMENTARY NOTES
Langley Technical Monitor: Burnell T. McKissick

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified-Unlimited
Subject Category 03 Distribution: Nonstandard
Availability: NASA CASI (301) 621-0390

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The Aircraft Vortex Spacing System (AVOSS), a set of algorithms to determine aircraft spacing according to wake vortex behavior prediction, requires turbulence profiles to appropriately determine arrival and departure aircraft spacing. The ambient atmospheric turbulence profile must always be produced, even if the result is an arbitrary (canned) profile. The original turbulence profile code was generated By North Carolina State University and used in a non-real-time environment in the past. All the input parameters could be carefully selected and screened prior to input. Since this code must run in real-time using actual measurements in the field as input, it became imperative to begin a data checking and screening process as part of the real-time implementation. The process described herein is a step towards ensuring that the best possible turbulence profile is always provided to AVOSS. Data fill-ins, constant profiles and arbitrary profiles are used only as a last resort, but are essential to ensure uninterrupted application of AVOSS.

14. SUBJECT TERMS
Aircraft wakes; Wake vortices; AVOSS; Atmospheric turbulence; Turbulence profile

15. NUMBER OF PAGES
14

16. PRICE CODE
A03

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL