A User's Guide to the Defence Scientist Career Progression Model

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Technical Note

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Abstract

This technical note is a user's guide for the Defence Scientist Career Progression Model developed using the *Arena* software package. The model was developed to predict the demographics of CORA's OR scientists. It's key assumptions, the historical data upon which they was based, and model outputs have been reported in a separate technical report. This document is meant to provide users with technical details required to understand and run the model, as well as to change the values of key parameters as more data is accumulated, or to run different scenarios.

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1 Introduction

In light of the recent growth of DRDC-CORA's Defence Scientist (DS) population, which follows an extended hiring freeze, CORA's management asked CORT to develop a model to forecast the demographics of its DS's. The resulting study, which was based on historical HR data for CORA's OR scientists for 1997-2006, shed light on the organization's current and future personnel situation, and provided insight into suitable strategies to mitigate the effects of recent growth and the imminent retirement boom.[1]

The previously published report concentrated on the results from the model, and though the key inputs and assumption were outlined, a thorough documentation of the software was not presented. Proper documentation for future users was deemed important because it was envisioned that the model will be used periodically by CORA's management team. Future users may wish to update the parameters and assumptions governing the model as new HR data becomes available. For reasons that are explained in Reference [1], to date, only CORA's OR scientist population has been modeled. Modeling of the social scientist, strategic analyst and intelligence analyst populations may become feasible over time as the size of these subpopulations increases, and as sufficient historical HR data becomes available.

2 The DS Career Progression Model

The DS Career Progression Model is an entity-based simulation developed using the *Arena* software package [2] with input and output to an *Excel* spreadsheet. Both the *Arena* code and the *Excel* file are included as electronic annexes to this Technical Note as files *DSCPM.doe* and *DSCPM.xls* respectively. Users of the model will require a working knowledge of *Arena*, and, to run the model, access to a fully licensed version of *Arena* v.10.00 or higher.

The general assumptions of the model have been outlined in Reference [1] and it is assumed that users have acquainted themselves with the details of the model as described in this document. It is recommended that before reading ahead, users spend some time familiarizing themselves with the model in the *Arena* programming environment. This can be done by opening the *DSCPM.doe* file in *Arena* and running the simulation, preferably with Batch Run mode turned off to show animations and the Animation Speed Factor slider set to some small value so that individual entities can be followed as they move through the model. Alternately, one can refer to the screen shots provided in Annex B.

Much of the internal logic of the model is made transparent by *Arena*'s graphical user interface, and it is expected that a proficient user of *Arena* will find much of the model's logical flow easy to follow by examining the model in the *Arena* programming environment. The bulk of this document deals with subtleties of the code that requires some explanation, particularly when it comes to the extensive use of arrayed variables.

2.1 The DS Entity and Career Progression

The entities in *Arena* represent individual DS's. Each entity is described by a number of attributes that define it in terms of its career state. For our purposes, it is assumed that a DS is fully described by their DS level, pay increment, age, years of service as a DS, years spent in their current DS level, years spent in their current pay step, whether they are on leave without pay (LWOP), and whether they have recently received double pay increments or have had increments withheld. Each of these is defined as an attribute for the DS entity and is described in Table 1.

The attributes of each DS are initialized at the start of the simulation, and are updated annually by the Career Progression Model, with statistics accumulated for the population as a whole. In each simulation year, entities receive pay increments and promotions with probabilities based on historical trends. At the beginning of each year, new entities are hired, while others are attritted (via mid-career attrition or retirement) or go on LWOP. A schematic showing the logical flow of entities through the model (reproduced from Reference [1]) is shown in Figure 1.

Table 1: *Relevant attritubtes for the DS entity*

Attribute Name	Description
DS Level	Current DS level taking on values from 2 to 6.
Pay Increment	Current pay increment within the DS level.
DS Index	A single number representing the DS level and Pay increment (obtained by laying DS levels end to end, and assigning the number 1 to DS-2 increment 1, and incrementing from there up to number 47 for DS-6 increment 7).
Age	Age of DS (actually Current Year - Birth Year).
YIL	Years in Level. Number of years completed at current DS level.
YIS	Years in Step. Number of years completed at current pay increment.
YOS	Years of Service. Number of years completed as DS (including LWOP years).
YTR	Years to Retirement. Number of years remaining before reaching 55 years old, and 30 YOS.
CAT	Career Progression Rate. Takes on values of 1,2 or 3 for *Accelerated*, *Normal* or *Delayed* career progression. Initially, entities are assigned a *CAT* value of 2 unless they have previously received a double pay increment in their current DS level, or they have been held at their current pay increment longer than usual, in which case they are assigned a *CAT* value of 1 or 3 respectively
LWOP Flag	Takes on value of 1 when on LWOP. Required so that entities on LWOP are not counted in salary wage envelope calculation.
Error	Error checks along the way will change this from its initial value of 0 to some number which identifies where an error occurred.

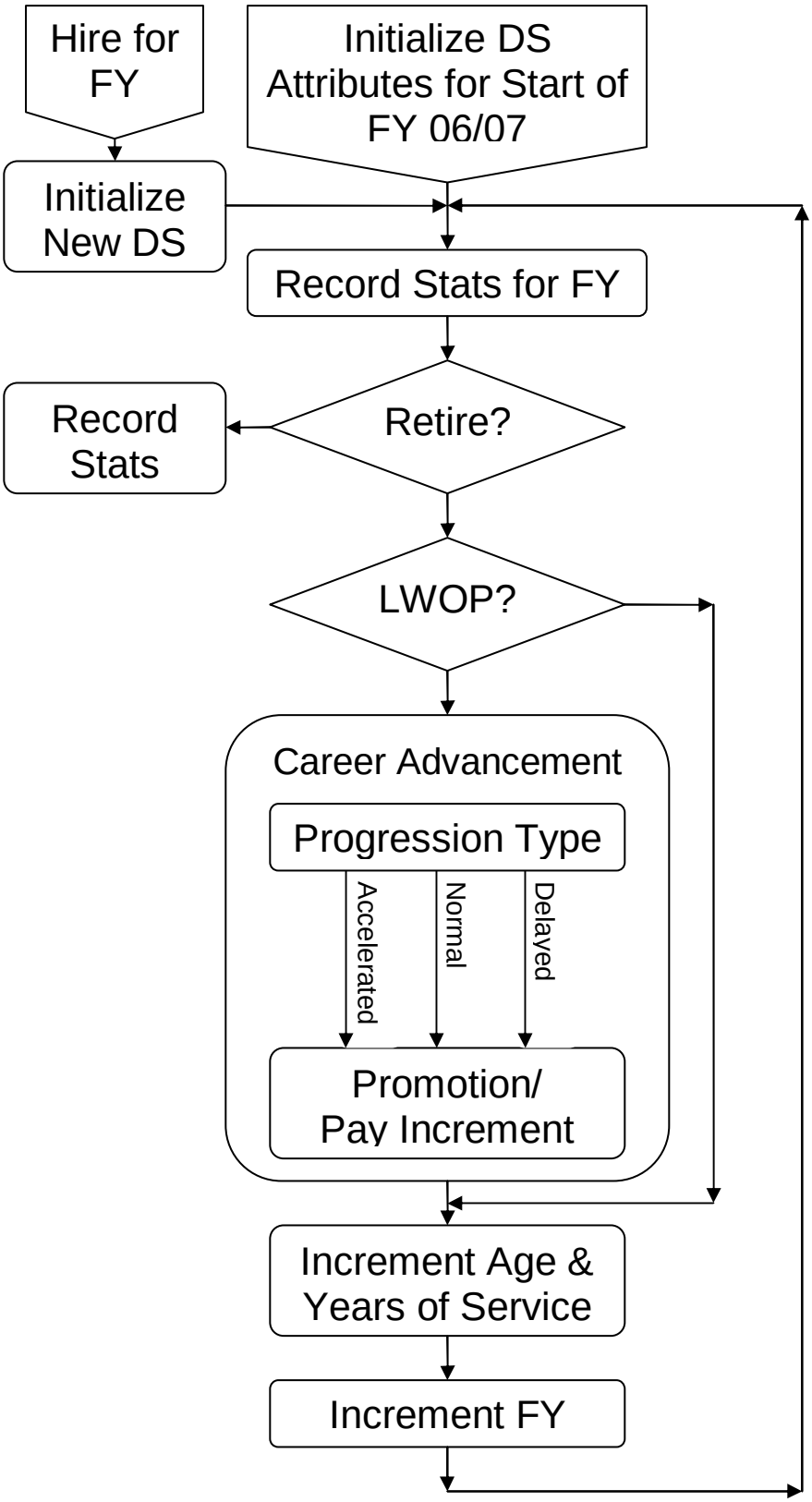

Figure 1: *Logical flow of entities through the model*

3 A Guide to Using the Model

3.1 Data Input from *Excel*

Entity attributes are initialized for the DS population at the start of the simulation from an *Excel* input file. The *Excel* workbook (*DSCPM.xls*) contains a named range called "*DataRange*" in which each row corresponds to an individual DS and each columns correspond to the fields: DS level, Pay Increment, YOS, Age, CAT, YIL, YIS, and LWOP Flag (see Table 1 for a description of each). One entity is created for each row in the range and the column values are assigned to entity attributes of the same name. All this happens in the "Create DS and Initialize" submodel. Care should be taken to ensure that the number of DS's that are in the *Arena* model at the start of the simulation corresponds to the number that are listed in the "*DataRange*". Data that falls outside the "*DataRange*" range will not be read by *Arena*, while empty cells within the range will generate errors.

3.2 Running the Arena Model

The model is run by opening the *DSCPM.doe* file in a fully licensed version of Arena (v.10.00 or higher), and pressing F5, or clicking on the "Go" icon in the Standard toolbar. It is suggested that the simulation be run in Batch Run mode (in the menu under Tools→Run Control→Batch Run). This significantly decreases execution time by not displaying animations. It is also important to make sure that the *Excel* input/output file (*DSCPM.xls*) is closed so that errors do not occur related to conflicts in accessing the file by *Arena* and *Excel*.

3.3 Data Output to *Excel*

At the end of each fiscal year (where years correspond to seconds in *Arena*), statistics pertaining to the DS population are calculated. Each year, the number of entities at each DS level (*N_DS*) are tallied, as is the salary wage envelope (SWE), the number of entities with less than and more than 10 YOS (*N_lt10*, and *N_ge10*), and the number of entities on LWOP (*N_LWOP*). Also tallied are the number of entities who left through attrition in the preceding fiscal year as a function of DS Level (*N_retired*) and career stage (*Retire Past Ret Age*, *Retire LateCareer*, *Retire MidCareer*, and *Retire EarlyCareer*). See Table 2 for a description of the global variables corresponding to these quantities.

Before the start of the next fiscal year a "Report" entity is created which initializes output of the tallied variables to the "*OutputRange*" named range in the *Excel* spreadsheet. A new line is written for each fiscal year. Once the line is written, the variables are reset, the next fiscal year is commenced (through a signal initialized by the "Report" entity), and the "Report" entity is discarded.

3.4 Processing the Output Using Macros in *Excel*

The stochastic nature of the model means that the simulation should be run for multiple replication (200 was used previously) and the outputs averaged. However, running averages are not kept in *Arena* from replication to replication. The averaging must therefore by done in *Excel*.

Excel macros were recorded to facilitate this labor-intensive process. To run the macro, place the cursor on cell *N13* in the *InputOuput* worksheet of the *Excel* file, then press *Ctrl+Shift+a*, or run *Macro 6* from Tools→Macros→Macros in the Menu. This will create a copy of the *Output Template* worksheet with the averages and standard deviations for each year.[1] The resulting worksheet can be renamed based on the scenario used, and the *Arena* model can be re-initialized and then run again with another set of inputs.

[1]Note that in order for *Macro 6* to work correctly, the simulation length must be set to 21 seconds (i.e. 21 years), and the number of replications per simulation set to 200. Other settings for replication length and number of replications can be used, but *Macro 6* will produce nonsensical outputs if it were to be used on the resulting *Arena* data.

Table 2: *A Description of global variables used by the model*

Variable Name	Description
FY	Fiscal Year. Zero corresponds to current year (i.e. the year for which the simulation was initialized.)
SWE	Salary Wage Envelope. The total salary of all entities not on LWOP. Calculated yearly.
DS Level Mapping	Array (indexed over DS Index) which maps DS Index to DS Level
Pay Increment Mapping	Array (indexed over DS Index) which maps DS Index to Pay Increment
Beginning of DS	Array (indexed over DS Level) which maps DS Level to the first increment of the level in DS Index
Mapping Counter	A counter used to read in Mappings
Single Step Mapping	Array (indexed over DS Index) which maps the change in DS Index due to a single step
Double Step Mapping	Array (indexed over DS Index) which maps the change in DS Index due to a double step
Promotion Mapping	Array (indexed over DS Index) which maps the change in DS Index due to a promotion step
N_DS	Array (indexed over DS Level) containing the number of entities at each DS level
N_ge10	Number of entities having 10 YOS or more
N_lt10	Numer of entities having less than 10 YOS
N_LWOP	Number of entities on LWOP
N_Retired	Array (indexed over DS level) containing the number of entities retiring at each DS level
Accel Rule	Array (indexed over DS Index) containing the promotion rule at each DS Index for accelerated progression
Normal Rule	Array (indexed over DS Index) containing the promotion rule at each DS Index for normal progression
Pay Rate	
Retire EarlyCareer	Number of entities leaving through attrition with 5 YOS or less
Retire LateCareer	Number of entities leaving through attrition with more than 5 YOS and less than 20 YOS
Retire MidCareer	Number of entities leaving through attrition with 20 YOS or more, or between 1 and 5 YTR
Retire Past RetAge	Number of entities leaving through attrition with 0 YTR or less

4 Clarification of Some Technical Aspects of the Model

Thanks to the graphical way in which processes are depicted in *Arena*, as stated earlier, it is expected that, for the most part, the logic underlying the DS Career Progression Model can be understood by examining the code in the *Arena* programming environment. However, there are some technical aspects of how the model works that are not immediately clear from the code, and require some further clarification. In particular, it is necessary to explain how entities move through the DS Pay Plan (i.e. the set of DS levels and pay steps that determine a DS's pay), as they receive annual pay increments or promotions.

In reality, DS's do not move sequentially through every step of the DS Pay Plan, but rather take jumps from one place to another whenever they are awarded a pay increment or promotion. For example, upon reaching the top of one DS level, they do not necessarily go to the bottom of the next. Also, at some pay increments, it is normal for a DS to wait two years before receiving a pay step, while at others, one year is normal. The non-trivialities associated with movement through the Pay Plan have been coded into the simulation using a number of layers of logic as is described in the following paragraphs. The approach chosen, while not the simplest, leaves the code maximally robust, allowing for easy adoption of different progression schemes or changes to the pay plan structure.

An entity's position in the DS Pay Plan is defined by its *DS Level* and *Pay Increment* attributes (with DS Level ranging from 2 to 6, and the number of pay increments varying by DS Level). Rather than work with *DS Level* and *Pay Increment* we work with a single measure of the entity's position in the Pay Plan which we call *DS Index*, which ranges from 1 for DS-2.1 to 47 of DS-6.7. The *DS Index* becomes the index for several arrays that tell the program what happens to entities at that position in the Pay Plan. The mapping of *DS Level* and *Pay Increment* to/from *DS Index* is accomplished using three arrays: *Beginning of DS*, *DS Level Mapping*, and *Pay Increment Mapping*. The mapping is summarized in Figure 2, and the values that the latter two arrays take on is given in columns 2 and 3 of Table 3.

At each point in the DS Pay Plan (i.e. for each *DS Index*), there exists a rule for *normal* progression and a rule for *accelerated* progression, where a "rule" can be a single step, double step, promotion, etc.[2] The set of rules used in the model are defined in Table 4. Each point in the DS Pay Plan is then assigned a rule for *normal* and *accelerated* progression through a pair of arrays which are called *Normal Rule* and *Accel Rule* respectively.[3] The values contained in these arrays are given in columns 4 and 5 in Table 3.

During each simulation year, logic elsewhere in the model establishes whether an entity will receive an *accelerated*, *normal* or *delayed* step (based on their *CAT*, and *DS Index*, and

[2]For example, for *normal* progression, entities at the top of DS-2 (i.e. *DS Index=5*) are promoted, whereas, above the double barrier in DS-4 (*DS Index=21,22,23,24*), they receive a step every other year.

[3]*Delayed* progression needs no set of rules because it means a pay increment/promotion being held back, regardless of *DS Index*.

Table 3: *Arrays associated with progression through the DS Pay Plan*

Array Index	DS Level Mapping	Pay Increment Mapping	Normal Rule	Accel Rule	Single Step Mapping	Double Step Mapping	Pro-motion Mapping	Pay Rate
1	2	1	1	99	1	99	99	37621
2	2	2	1	99	1	99	99	41701
3	2	3	1	99	1	99	99	48058
4	2	4	1	99	1	99	99	49792
5	2	5	3	99	99	99	2	51953
6	3	1	1	99	1	99	99	51953
7	3	2	1	99	1	99	99	54117
8	3	3	1	2	1	2	99	56282
9	3	4	1	2	1	2	99	58445
10	3	5	1	7	1	2	3	60612
11	3	6	1	3	1	99	2	62778
12	3	7	3	3	99	99	1	64941
13	4	1	1	99	1	99	99	67929
14	4	2	1	99	1	99	99	69842
15	4	3	1	2	1	2	99	71754
16	4	4	1	2	1	2	99	73671
17	4	5	1	2	1	2	99	75580
18	4	6	1	7	1	2	8	77496
19	4	7	1	3	1	99	7	79410
20	4	8	4	3	1	99	6	81318
21	4	9	6	3	1	99	6	83238
22	4	10	6	3	1	99	6	85147
23	4	11	6	3	1	99	6	87063
24	4	12	6	3	1	99	6	88976
25	4	13	0	3	99	99	6	90890
26	5	1	1	99	1	99	99	83639
27	5	2	1	99	1	99	99	85788
28	5	3	1	2	1	2	99	87940
29	5	4	1	2	1	2	99	90088
30	5	5	1	2	1	2	99	92239
31	5	6	1	7	1	2	5	94390
32	5	7	1	3	1	99	5	96789
33	5	8	5	3	1	99	5	99168
34	5	9	6	3	1	99	5	101509
35	5	10	0	3	99	99	5	103849
36	6	1	1	99	1	99	99	97229
37	6	2	1	99	1	99	99	99619
38	6	3	1	2	1	2	99	102013
39	6	4	1	2	1	2	99	104406
40	6	5	1	7	1	2	4	106801
41	6	6	1	3	1	99	4	109188
42	6	7	0	3	99	99	4	111579
43	7	1	1	99	1	99	99	106555
44	7	2	1	99	1	99	99	108950
45	7	3	1	2	1	2	99	111345
46	7	4	1	1	1	99	99	113740
47	7	5	0	0	99	99	99	116135

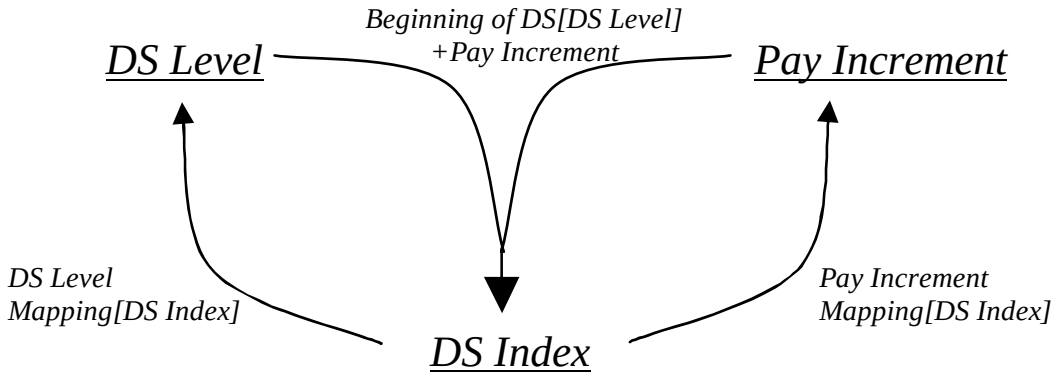

Figure 2: *Mapping of the DS Level and Pay Increment variables to/from the DS Index variable.*

Table 4: *Progression Rules*

Rules	Description
0	No step
1	Single Step
2	Double Step
3	Promotion
4	DS 4 double barrier: held for one year, then promoted 25% of the time and single step 75% of the time
5	DS 5 double barrier: held for one year, then promoted 10% of the time and single step 90% of the time
6	Step every other year
7	Double step 50% of the time, promotion 50% of the time
99	Error check: This should never happen

some random variables), and therefore (through the *Accel Rule* and *Normal Rule* arrays) whether they receive a single, pay increment, a double pay increment, a promotion, or change in their position in the Pay Plan. Once this is established, it is necessary to know where such a step moves the entity in terms of its *DS Index*. Thus, for each *DS Index*, we must define the number of steps moved for a single pay increment, a double pay increment and a promotion. This is done using three arrays called *Single Step Mapping*, *Double Step Mapping*, and *Promotion Mapping* whose contents are shown in columns 6, 7 and 8 in Table 3.

All these arrays (except for the *Beginning of DS* array) are defined in the *Excel* file in the "*Mapping*" named range in the *Mapping* worksheet and are read in at the beginning of the simulation. This allows progression through the pay plan to be changed easily.

To summarize, the following steps are taken in determining the annual changes in *DS Level* and *Pay Increment*:

1. the *DS Level* and *Pay Increment* are mapped onto *DS Index*;
2. based on the current *DS Index* and *CAT*, a decision is made regarding whether the entity takes a normal, accelerated or delayed step
3. based on the current *DS Index*, it is decided whether the normal, accelerated or delayed step means a single, double or no pay increment, or a promotion (using *Normal Rule* and *Accel Rule* arrays);
4. based on the step type, the *DS Index* is updated (using *Single Step Mapping*, *Double Step Mapping* and *Promotion Mapping* arrays)
5. *DS Index* is mapped back to *DS Level* and *Pay Increment*

This logic is depicted schematically in Figure 3.

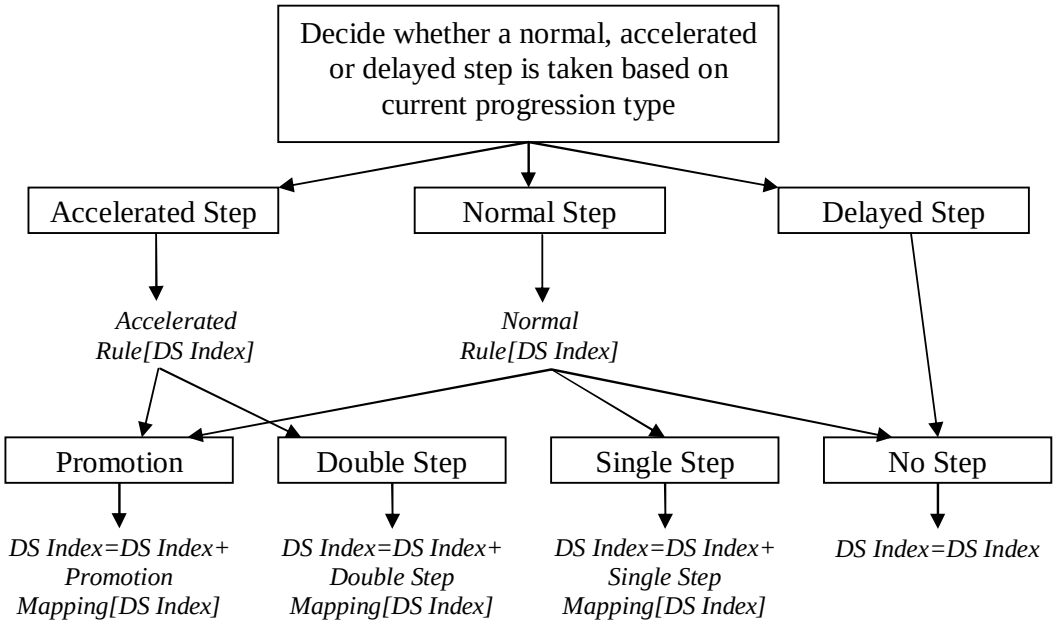

Figure 3: *Schematic of DS movement through the Pay Plan.*

5 Summary

In summary, this User's Guide has documented the inner working code and logic for the future users of the DS Career Progression Mode. It has outlined how the program interfaces with an *Excel* spreadsheet for input and output, and how to use the *Excel* macros to perform data averaging. It also described some of the technical subtleties of the code arising from the way in which career progression through the DS Pay Plan was defined.

It is expected that this User's Guide will prove sufficient for future users of the DS Career Progression Model, when used in conjunction with the Technical Report outlining the model's assumptions.

References

1. Eles, P.T. and Massel, P.L. (2006). CORA's OR Scientists: Analysis of Past Hiring, Career Progression, and Attrition Trends, and Development of a Model to Forecast Future Demographics. (Technical Report DRDC CORA TR 2006-xxx). DRDC - Centre for Operational Research and Analysis. Ottawa, Canada.

2. Arena version 10.00.00, Rockwell Software Inc. (Online). `www.arenasimulation.com` (September 2006).

Annex A
Electronic Annexes

An electronic copy of the *Arena* source code for the DS Career Progression Model accompanies this Technical Note. The program, named *DSCPM.doe* is compatible with *Arena* versions 10.00 or higher. The accompanying *Excel* workbook, named *DSCPM.xls*, is required to run the model and should reside in the same directory as the source code. The workbook was created in *Microsoft Office Excel 2003* and should be compatible with all newer version of *Excel*.

Annex B
DS Career Progression Model Screen Shots

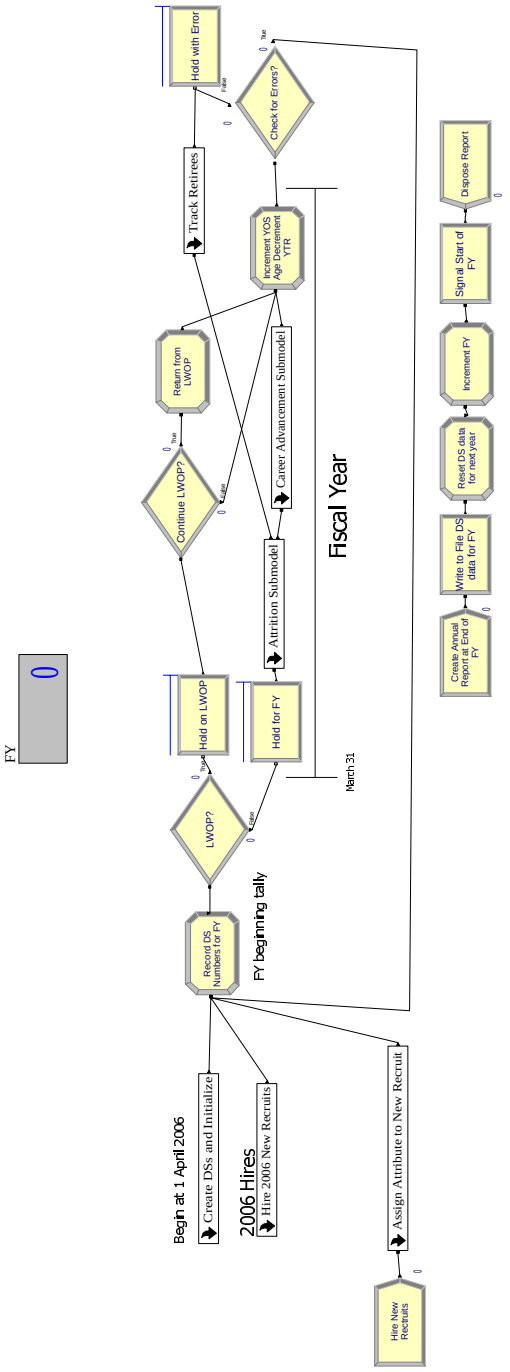

Figure B.1: *Screen shot of the Arena Model.*

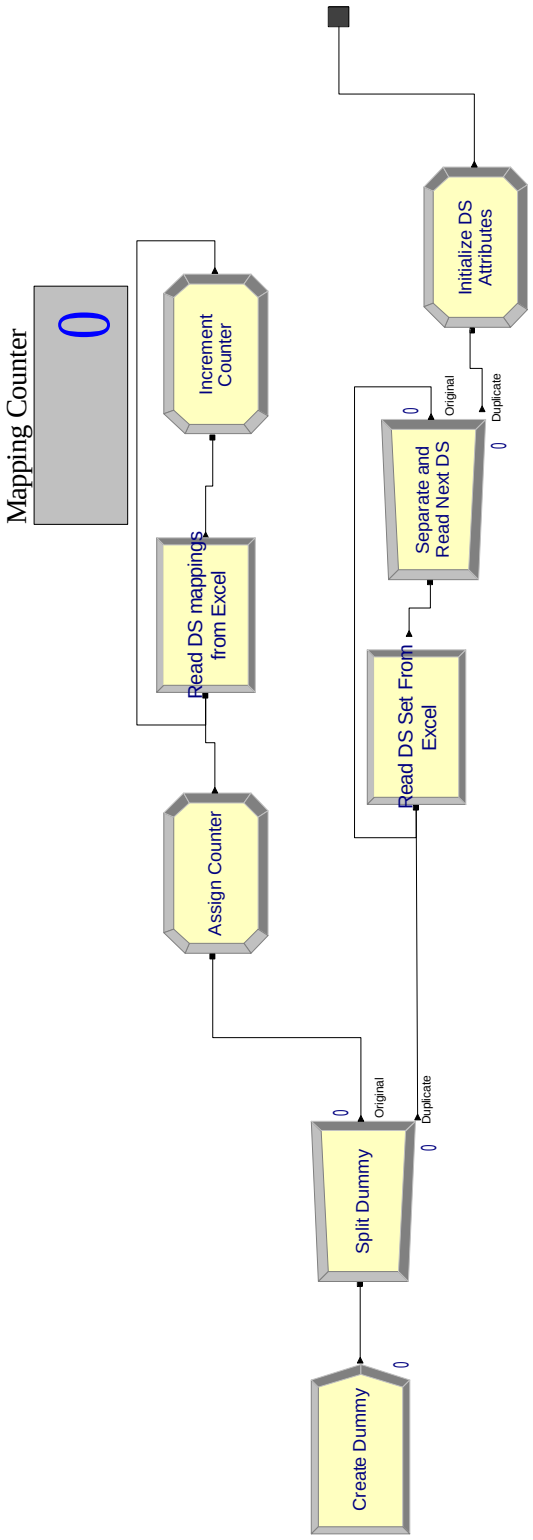

Figure B.2: *Screen shot of the submodel to initialize DS entities and read mappings from Excel file.*

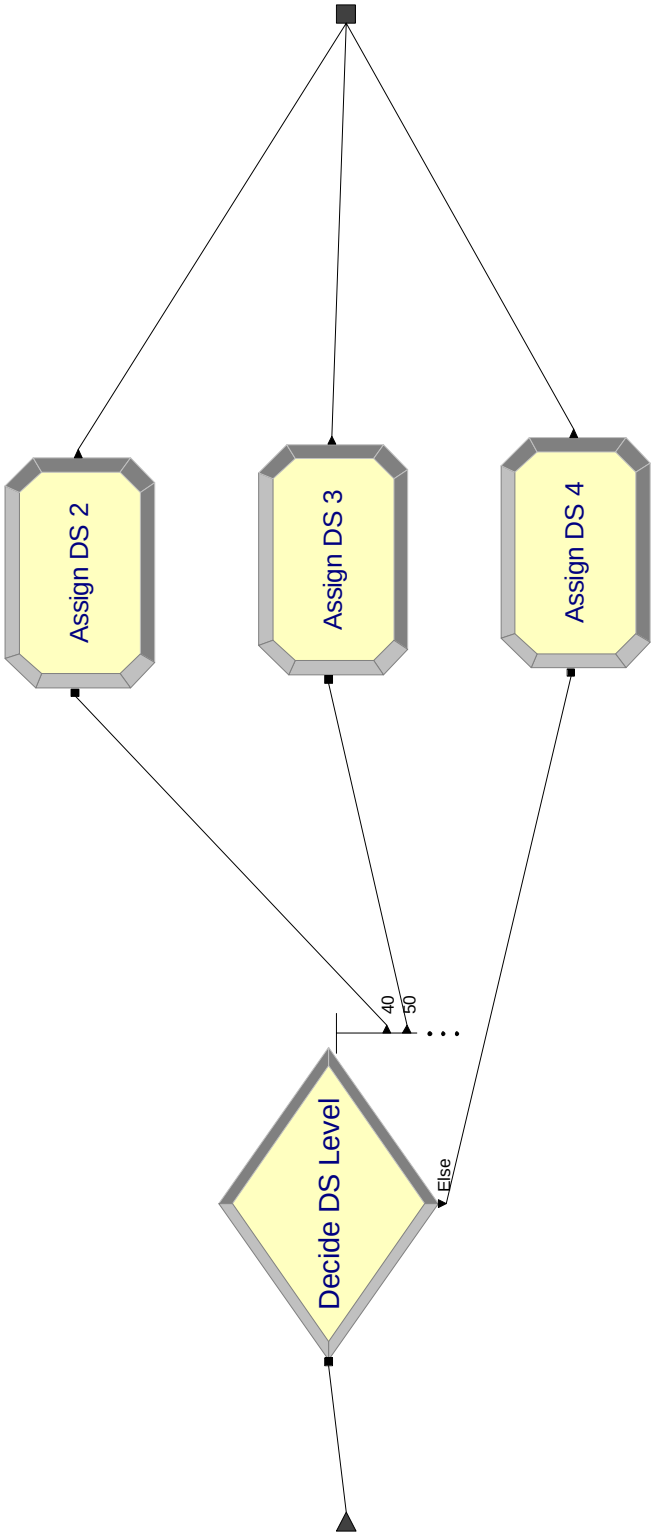

Figure B.3: *Screen shot of the Hiring Submodel.*

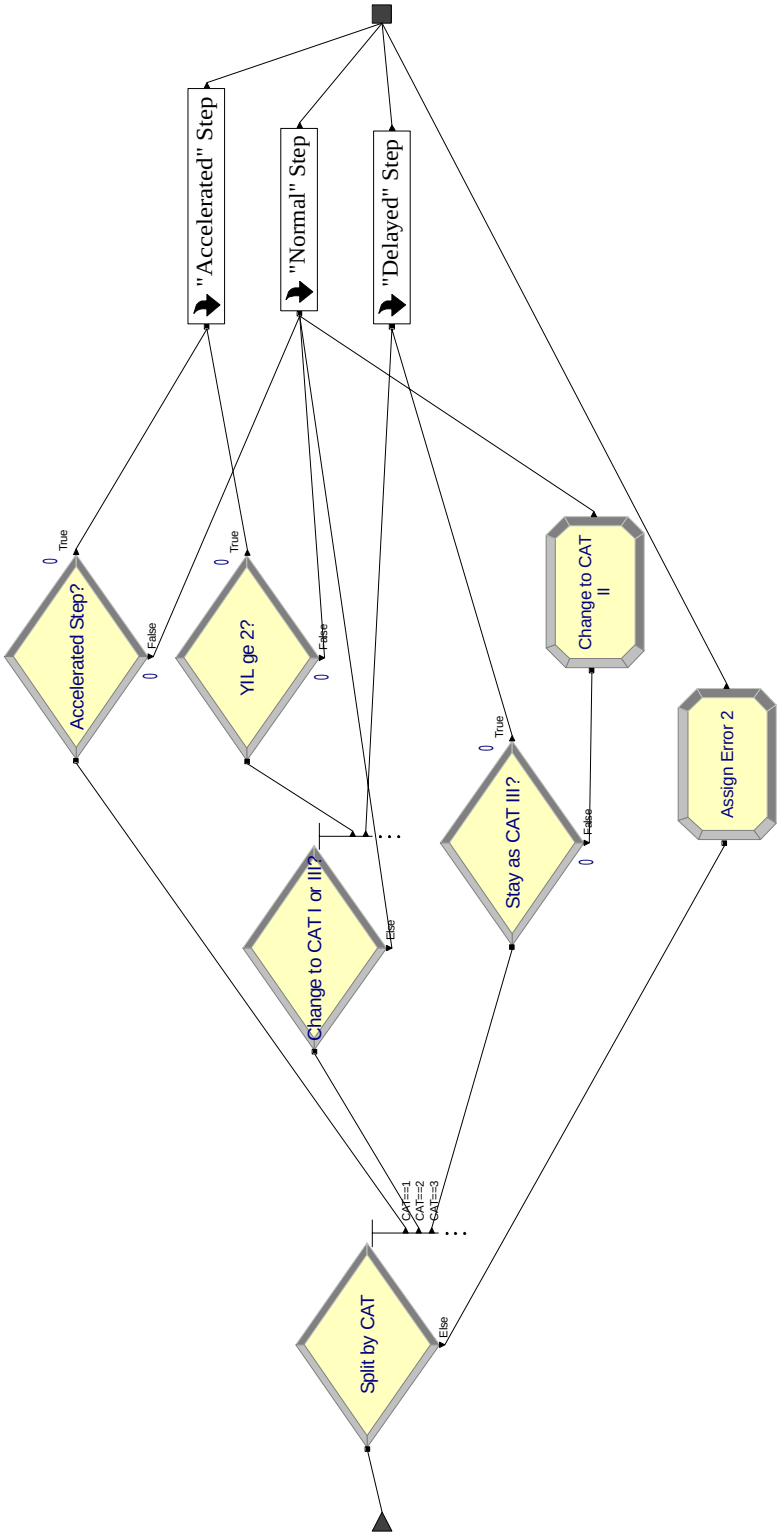

Figure B.4: *Screen shot of the Career Advancement Submodel.*

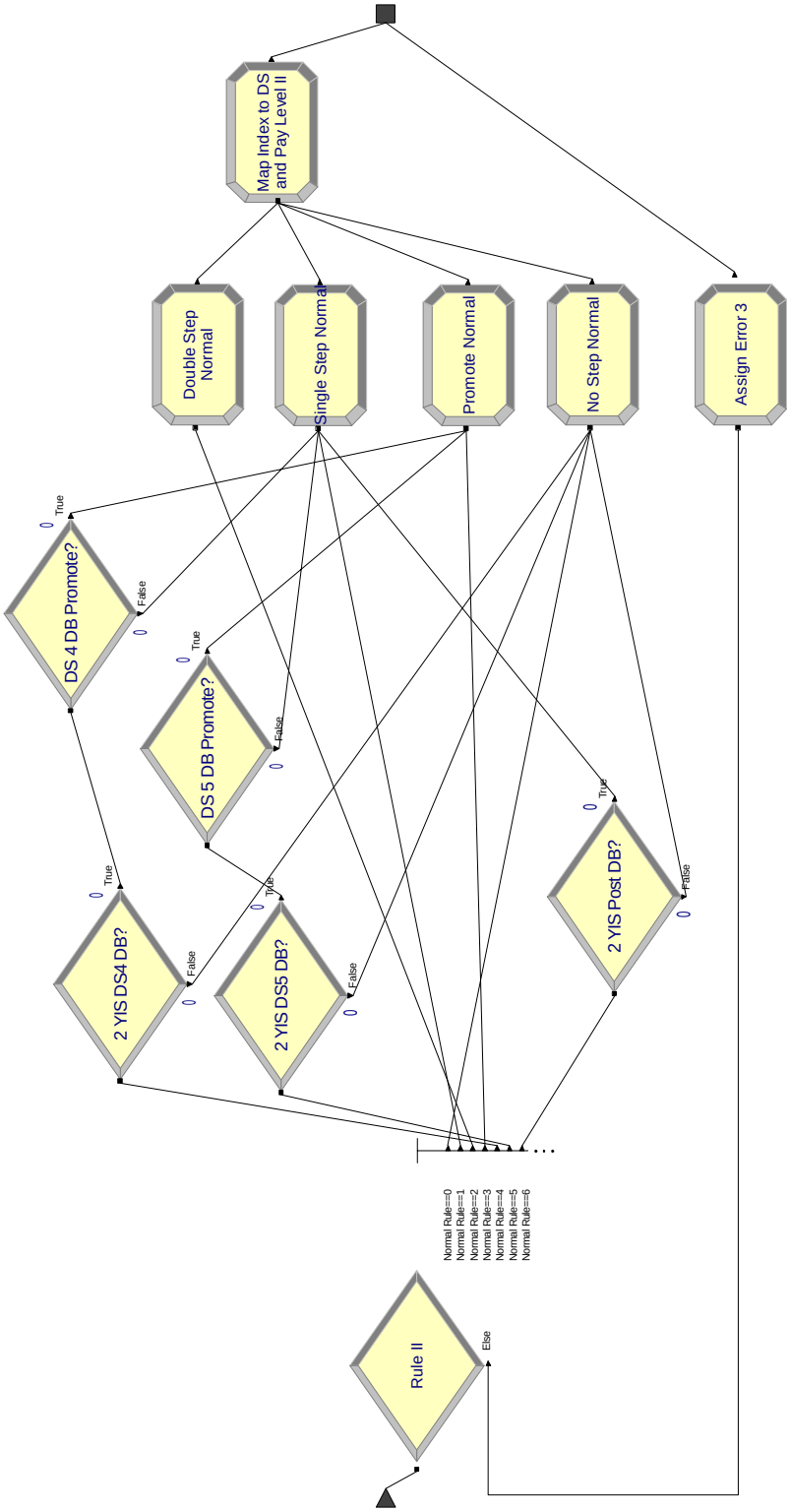

Figure B.5: *Screen shot of the Normal Step Submodel.*

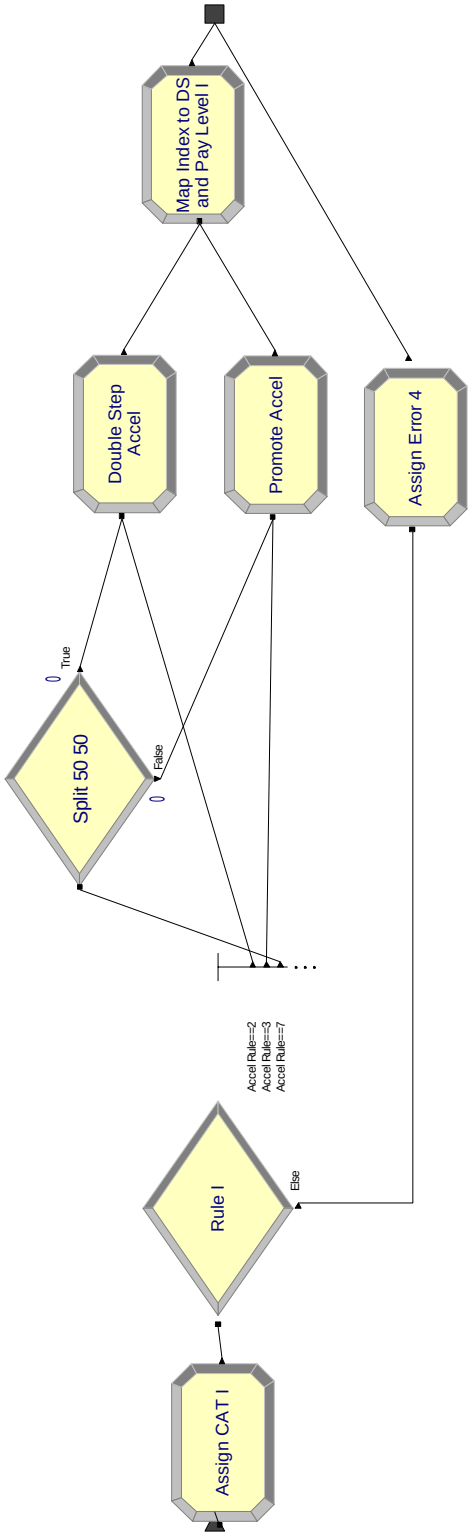

Figure B.6: *Screen shot of the Accelerated Step Submodel.*

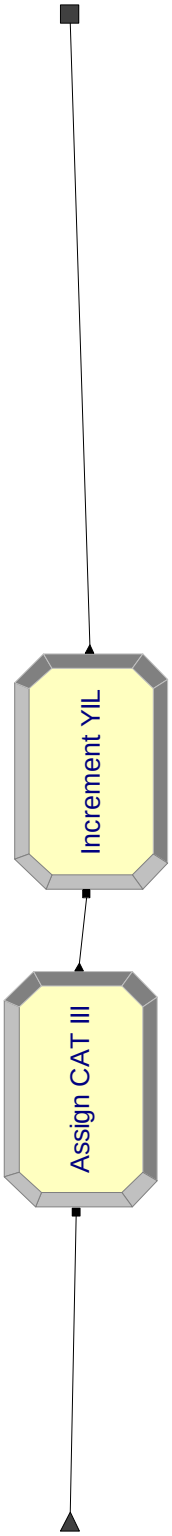

Figure B.7: *Screen shot of the Delayed Step Submodel.*

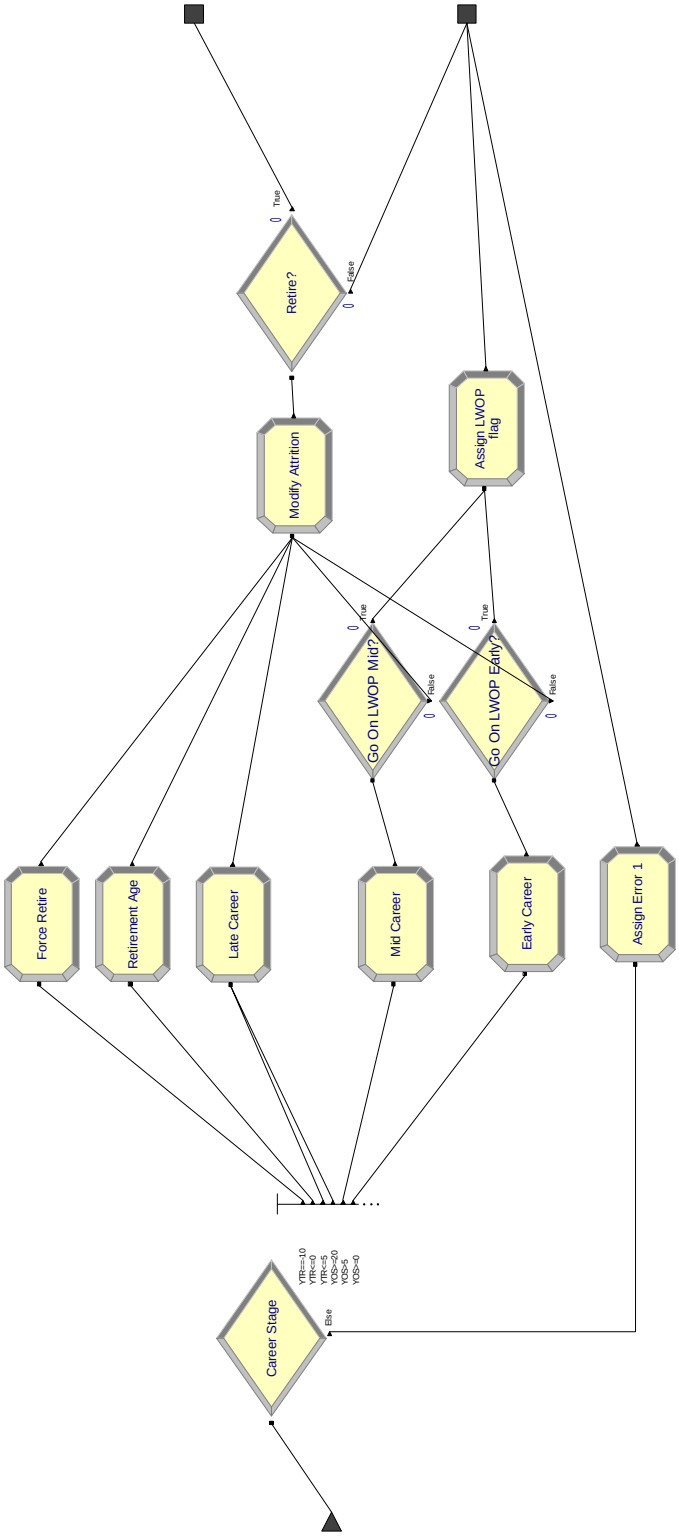

Figure B.8: *Screen shot of the Attrition Submodel.*

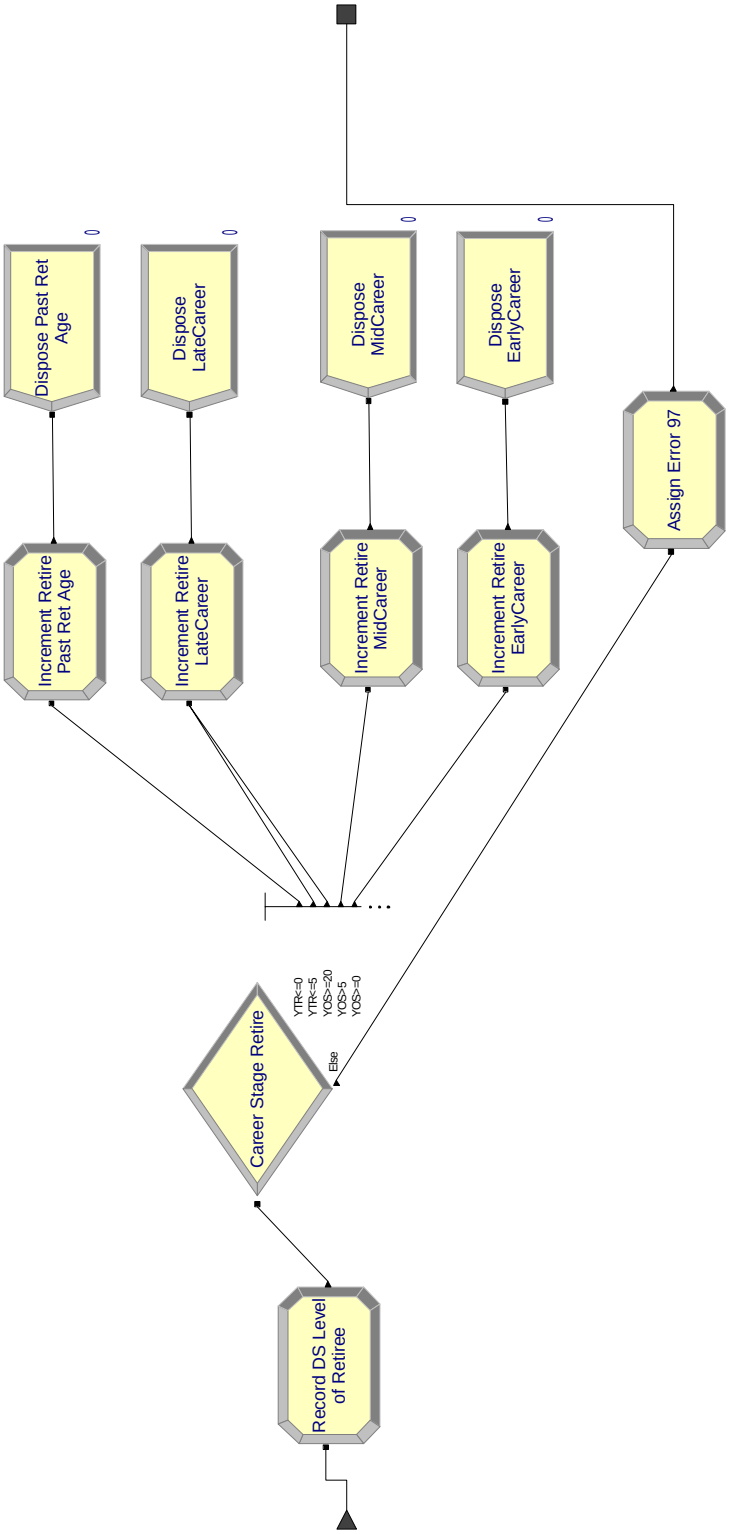

Figure B.9: *Screen shot of the Attrition Tracking Submodel.*

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This technical note is a user's guide for the Defence Scientist Career Progression Model developed using the *Arena* software package. The model was developed to predict the demographics of CORA's OR scientists. It's key assumptions, the historical data upon which they was based, and model outputs have been reported in a separate technical report. This document is meant to provide users with technical details required to understand and run the model, as well as to change the values of key parameters as more data is accumulated, or to run different scenarios.

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Defence Scientist, DS, Defence Scientific Services Group, Pay Plan, trends, hiring, attrition, career progression, demographics

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