Application of System Dynamics to Human Resource Management of Canadian Naval Reserves

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Abstract

The mission of the Canadian Naval Reserves (NAVRES) is to provide trained reservists to meet various challenges of its combat and support elements to enable Canada to meet its objectives in time of peace, crisis or war. In order to sustain effectively and economically NAVRES has to manage an optimal number of the trained reservists in meeting their demands. Over time demand of the trained reservists has been increased. The responsibilities and tasks of meeting the growing demands of the trained reservists can be daunting, risky, and costly without the proper knowledge and tools for evaluating the nature, structure, and potential behavior of the different components of the NAVRES as they relate to the mission of the organization. This paper describes a model that can assist management of the NAVRES to deal with the challenges organization is faced with; as well as plan, manage and drive the future and strategic focus of the organization in its desired direction. Model incorporates the underlying interconnections among different components of the NAVRES that could help to understand the underlying causes of the challenges faced by the NAVRES. The model estimates the requirements of the trained reservists at different levels under various scenarios as well as provides a laboratory environment for the decision makers to test virtually unlimited number of strategies (i.e. "What ifs?" scenarios) that would accelerate their learning and help them in designing robust and effective strategies to successfully manage their resources strategically.

Background Information

The Naval Reserve (NAVRES) is a major component of the Canadian Navy. Over the last several years mission of the NAVRES has been expanded from augmenting the Regular Canadian Force to providing trained reservists to the Maritime Command to meet the challenges of its combat and support elements to enable Canada to meet its objectives in time of peace, crisis or war. Currently, responsibilities of the NAVRES include supporting a network of 24 Naval Reserve Divisions (NRDs) located in major cities across the Canada. These NRDs offer training activities to the reservists to learn more about their respective occupations while practical training is conducted at sea. Besides responsibilities at NRDs, NAVRES has to manage tasks such as providing two standing Port Inspection Diver Teams and, as required, Naval Cooperation and Guidance for Shipping (NCAGS) and Port Security Units. The Naval Reservists also occupy recruitment positions at National Defence and Naval Reserve Headquarters. In addition to all these responsibilities and various tasks, in 1998 NAVRES has been given the responsibility of manning and providing support to 10 to 12 Maritime Coastal Defence Vessels (MCDVs).

These various responsibilities and tasks have created multiple levels of interdependency and complexity for the NAVRES, which requires synergy to function as a unit with common goal of meeting its growing demands effectively and economically. The tasks of meeting the growing demands of the trained reservists effectively and economically can be daunting, risky, and costly without the proper knowledge and tools for evaluating the nature, structure, and potential behavior of the different components of the NAVRES as they relate to the goals of the organization. The decision makers at the NAVRES need the necessary competency and decision support tools that can help them to deal with the challenges organization is faced with; as well as plan, manage and drive the future and strategic focus of the organization in its desired direction.

The existing total strength of the NAVRES is approximately 3837 reservists. This total strength includes a Trained Effective Strength (TES) of 2810 and 1027 reservists on the Basic Training List (BTL), i.e. having yet to be qualified in their occupation and considered as non-employable. NAVRES is a unique organization, with several distinct employment patterns influencing its distribution across various occupations and ranks. These employment patterns include part-time and full-time employment, short to medium-time employment and continuous employment in various positions.

Challenges faced by the NAVRES

Currently, NAVRES is faced with numerous challenges to meet the demand of trained reservists to carry out the multiple tasks mentioned above. Some of these challenges arise from effectively managing the diversified responsibilities of the NAVRES related to recruiting, training, and retaining the reservists. For examples these challenges are:

- At the recruitment stage one of the challenges is to find out the optimal number of intake recruitment, and the appropriate time of recruitment to match the needs of various distinct employment patterns with the applicants' interests, availability, and level of qualification.

- The challenges related to training include availability of the trained instructors to offer the training courses on time to control the delay in training and also to maintain the training standards similar to the Regular Forces. Also, availability of the reservists to take the courses on time is a challenge because many reservists are only available during the summer break from their schools or available during the vacations from their civilian employment. Hence, career progression of reservists depends on their commitments in civilian life, and also availability of resources including instructors and school facilities to offer courses at their regular time.

- After successful training the challenge is to retain the trained reservists. Retention has always been a concern for the NAVRES. During the first four years of service 40 percent of the enrolled members leave the organization. The reasons for leaving include conflicts with one's job, educational and family commitments, workload conditions, short-term contract, fear of going to war, failure from basic training, lengthy training time, less opportunities for promotion, regional issues, lesser benefits relative to regular force, medical fitness, and sometimes life style.

These different challenges are not independent to each other, they do interact to one another over time. For example, leaving of the trained reservists could create a shortfall of personnel in different ranks that could influence overall performance of the NAVRES. Activities of one stage are interdependence to the activities of other stages. The changes in the recruitment time at the recruitment stage could influence the activities of the training stage. And also changes in the recruiting intake could influence the requirements at training stage, and if certain requirements at training stage are not available then that might create a delay in the training, and eventually impact on the overall performance of the NAVRES to fulfill its assigned mandate.

Objectives of the study

The objective of this study is to develop a simulation model using System Dynamics methodology. The application of this model will include accurately estimating the human resources requirements of different trades of Non Commission Members (NCM) and Officers from enrollment stage to the career progression ranks. In addition, model will help the management in assessing the impact of different strategies aimed at effectively and economically sustaining the availability of the sufficient number of trained reservists in meeting their demands. For example, analyzing the impact of a strategy related to improving the working conditions of the reservists to reduce the attrition rate that could influence recruitment intake, and result in changing the requirements at the training stages, and eventually changing the overall performance of the NAVRES to meet its assigned mandate. The model provides a laboratory environment for the decision makers to test virtually unlimited number of strategies (i.e. “What ifs?” scenarios) that would accelerate their learning and help them in designing robust and effective strategies to successfully manage their resources strategically.

Methodology

This study has been carried out in four phases over the length of three months. The details of tasks performed during each phase are discussed in the following. A team of three officials from the NAVRES who have been involved in human resource management issues of the NAVRES was actively involved through out the study for reviewing the outcomes of each phase.

Phase I: Problem articulation and identification of key drivers

The purpose of the tasks carried out during Phase I was to understand the challenges faced by the NAVRES, and identify the underlying causes for these challenges. The main activities performed during this phase include: 1) Workshop on System Dynamics Methodology, and 2) Data collection and information gathering

A workshop on System Dynamics methodology was offered to a group of 15 members from the NAVRES. The workshop provided an opportunity to the participants to understand the rationale for using System Dynamics methodology in this study, and also an opportunity for the author to understand the challenges of the NAVRES. The contents covered during the workshop are as follows:

- Introduction to System Dynamics perspective
- Fundamental principles of System Dynamics Methodology
- Basic System Archetypes that repeat across diverse situations
- Demo of System Dynamics based tools including a prototype NAVRES model
- Engaging participants to articulate the challenges faced by the NAVRES

In order to understand the dynamics of reservists over the last several years, the historic data from 2001 to 2006 was obtained. This data include extensive details such as:

- Enrollment rates of all Officers and NCM
- Attrition rates of all Officers and NCM
- Promotion rates of all Officers and NCM s
- Manning requirements of all Officers and NCM trades by their ranks year-wise. Manning requirements refers to demand of the reservists that depend upon various responsibilities such as NRDs, Appointments, PSU, NCAGS, CSP, and Incremental positions.
- Actual effective strength of all NCM and Officers
- Statistics related to all Officers and NCM courses including course duration, number of reservists who completed or failed courses.
- Actual availability of all Officers and NCM.

In addition, some project reports carried out by Jenkins (2004, 2005) related to human resource management of the NAVRES were also gathered. These reports helped in understanding the challenges faced by the NAVRES and also reasons for attrition rate as gathered through surveys from the reservists of various trades and ranks. Based on the information gathered in Phase I, key drivers to the challenges faced by the NAVRES are identified. Some of these challenges are described earlier in this paper.

Phase II: Formulation of Dynamics Hypothesis

Based on historic data collected, it is found that there is a gap between demand and available number of reservists for most of the trades. The reasons for the gap might include inaccurate estimate of enrollment rates, higher attrition rates, lower availability of the reservists to take the training courses on time, and lower availability of the instructors to offer the training courses on time. In order to understand the possible reasons for the gap, dynamic hypothesis is formulated. The dynamic hypothesis defines how different elements of the NAVRES are interconnected to each other. Development of the dynamic hypothesis followed the procedure of identifying linkages (cause and effect) between different elements of the NAVRES, and completing the feedback loops to replicate the underlying structure of the NAVRES. The information gathered during the Phase I from statistical data, written reports/documents, and from discussions with the team members from NAVRES are used to delineate the interconnections between elements of the NAVRES.

Figure 1 illustrates the dynamics hypothesis of the NAVRES model. Formulation of the dynamics hypothesis followed the circular causality which is the founding principal of the System Dynamics approach. The circular causality captures how certain conditions of the system lead to decisions, and how decisions cause actions that in turn change the conditions. For example, if conditions are such as there is a gap between required and available trained reservists then decision would be to enroll more individuals to fill the gap, and actions would be recruiting individuals that in turn will reduce the gap between required and available reservists.

The dynamic hypothesis shown in the Figure 1 incorporates the underlying interconnections among different components of the NAVRES that could help to describe the possible causes of the challenges faced by the NAVRES. These interconnections form a number of positive and negative feedback loops that interact to each other over time. As shown in the figure 1, it is assumed that additional requirement of reservists at a certain rank would depend on demand of reservists at that rank, attrition rate, promotion rate to next rank, and available reservists at that rank. This additional requirement of reservists would set the need for promotion rate from junior rank. The promotion rate from junior rank would depend on the available reservists who qualify for the promotion. In order to qualify for the promotion, reservists must have completed that required training courses and required service duration. The completion of training courses would depend on the availability of instructors as well as availability of the reservists to take the training courses.

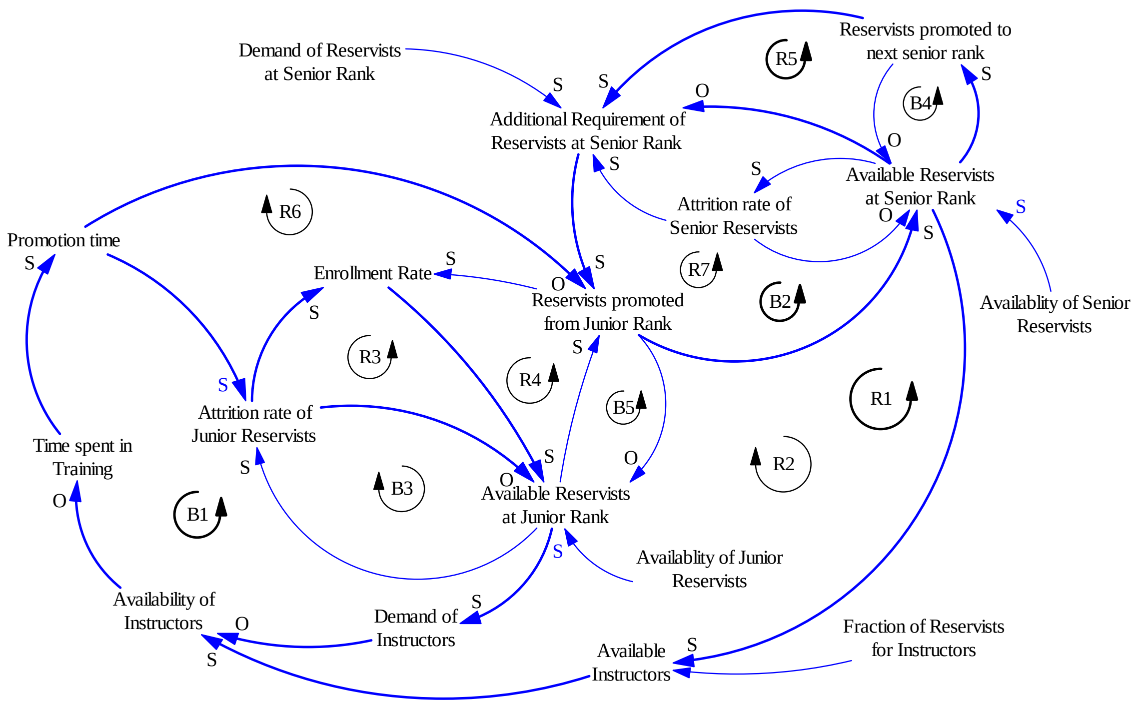

Figure 1 Dynamic Hypothesis of the NAVRES model

Phase III: Development of Simulation Model

In this phase System Dynamics simulation model is developed. Development of the simulation model mainly follows the ageing chain concept of Sterman (2000). Based on the NAVRES requirement, ten trades from the NCM and four trades from the Officers are modeled. In the model these trades are distinguished by subscripts. The stock-flow structures for career progression of Officers are shown in Figure 2 and 3. And Figure 4 and 5 depicts the career progression NCM. In order to make the sketches clear, some of the variables and linkages particularly on figures from 3 to 5 are not shown. And due to space limitation sketches of the simulation model related to calculations for estimating demand and effective strength of the NAVRES are also not shown.

The level variables in figure 2 and 3 refer to ranks of Officers, and levels in figure 4 and 5 refer to ranks of NCM. The Officers start their career as Naval Cadet (NCDT) and NCM start from Ordinary Seaman (OS). Both Officers and NCM progress in their career as they complete required qualifications and service duration. The time to complete required qualifications and service duration is represented as promotion time in the model. The promotion times for all Officers and NCM trades by ranks are calibrated based on promotion data from 2001 to 2006.

The model assumes fraction of Officers and NCM are released from each rank that represent reservists who quit or retired. The parameters “fraction of released” for all Officers and NCM trades by ranks are also calibrated based on released data from 2001 to 2006.

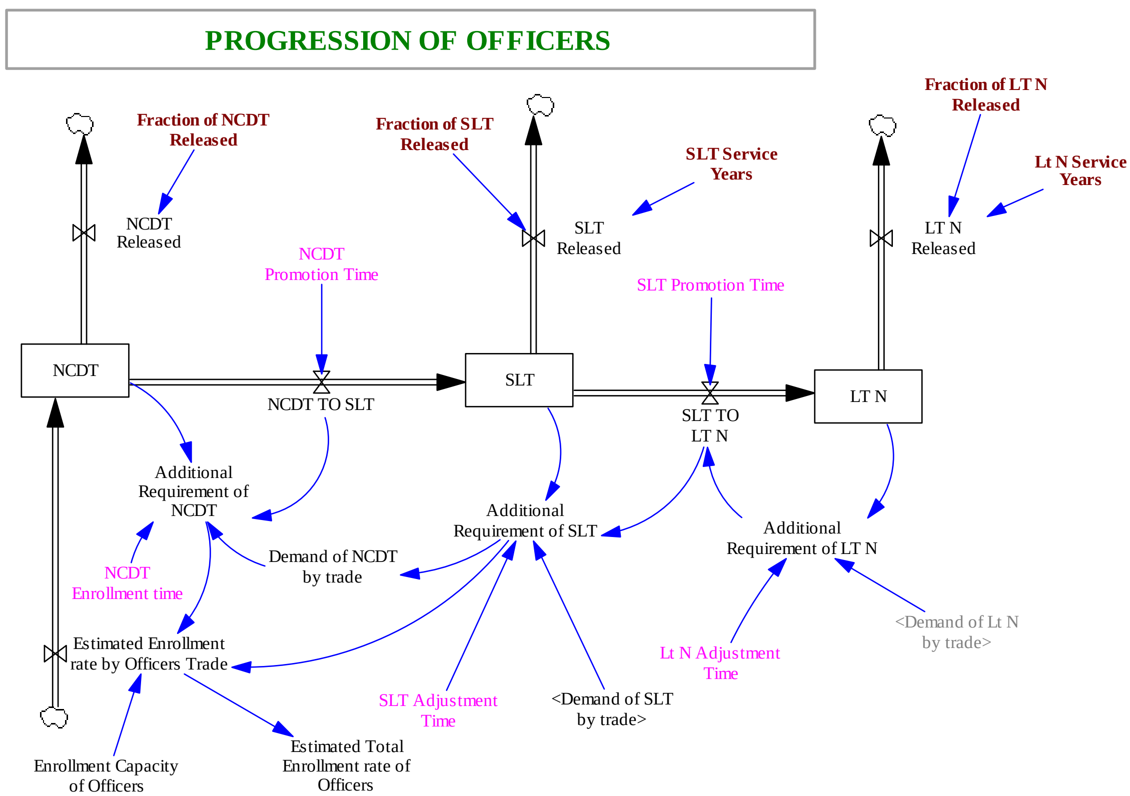

Figure 2: Stock-flow structure of the Officers progress

As shown in figure 2 to 5, additional requirement of reservists at each rank is estimated separately. Additional requirement of reservists refers to the number of reservists required for a certain trade and rank in addition to the existing number of available reservists in effective strength (i.e., stock variable). The estimated additional requirement for each trade is used to estimate the enrollment rate. It is assumed that additional requirement of reservists depend on demand of reservists, available number of reservists, averaged number of released reservists, and adjustment time. The demand of all Officers and NCM trades by ranks is externally determined using data provided by the NAVRES.

The model imports input data from MS Excel to estimate the demand. This provides ability to the management to modify and update the input data for future years very easily.

The model assumes fraction of Officers and NCM are released from each rank that represent reservists who quit or retired. The parameters "fraction of released" for all trades and ranks considered in the model represent the averaged attrition rates based on historic data from 2001 to 2005.

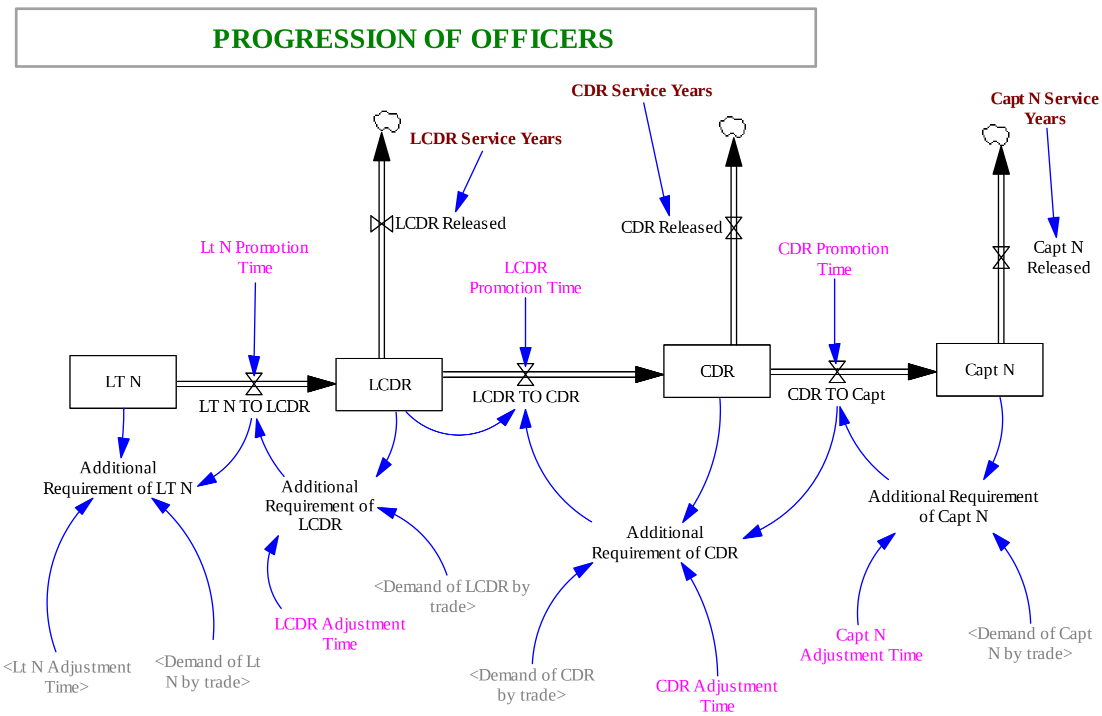

Figure 3: Stock-flow structure of the Officers progression

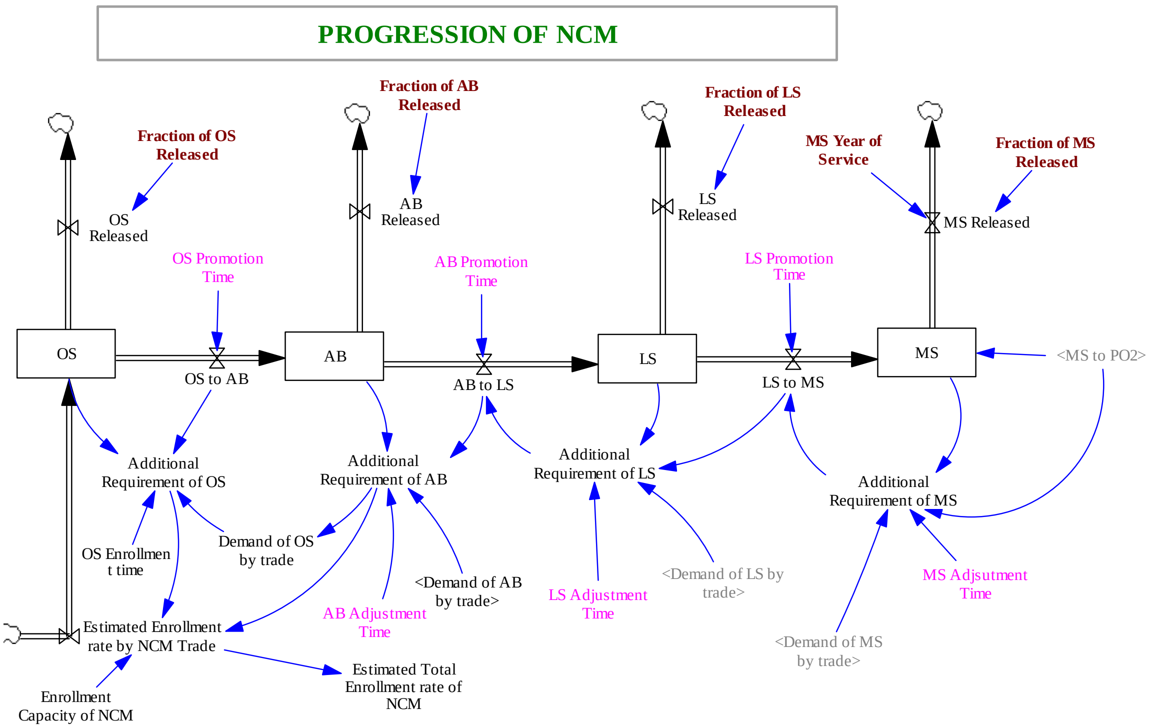

Figure 4: Stock-flow structure of the NCM progression

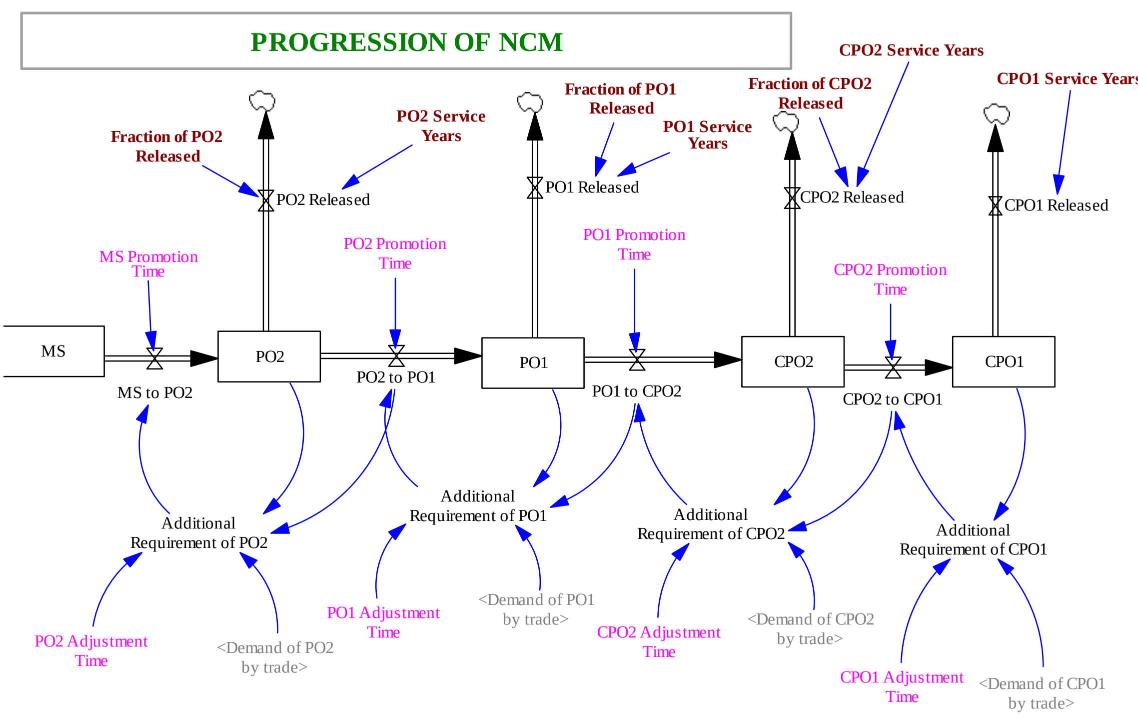

Figure 5: Stock-flow structure of the NCMs progression

Developing simulation model is an iterative process and time consuming task, which requires a number of iterations to obtain a model that produces an outcome close to reality in terms of producing the historic data and also in terms of developing consistency between the model structure and the real life structure.

Phase IV: Model Verification and Testing

Model verification and testing focused on carefully examining each component of the simulation model, and comparing the model outcomes with the historic data from 2001 to 2006. For example, examining each component of the model includes probing mathematical relationships between different variables of the model, verifying the model inputs from MS Excel file, and verifying the unit consistency of the model.

In terms of developing a consistency between the model outcomes and the historic data, calibration of the model parameters is carried out based on data from 2001 to 2006. The advanced features of the Software Vensim are applied to make the calibration process efficient. The calibration procedure is repeated several times by adjusting the model relationships and parameters in response to discrepancy between model results and historic data.

In this phase some additional model verification tests are also carried out. These tests include "Extreme Conditions Tests and "Behavior Anomaly Test". These tests are very useful for model verification before applying the model to evaluate the policy scenarios. In the "Extreme Condition Test" results of the model are analyzed under the extreme values of its inputs (i.e. minimum and maximum values of input). This test helped to understand how model will respond when subject to extreme conditions of its inputs. The "Behavior Anomaly Test" is another test that is carried out to analyze the model outcomes in response to changes in the some of the model assumptions.

The outcomes of the model are compared with historic data for 2001 to 2006. As an example, Figure 6 to 13 shows the comparison between model estimates and data.

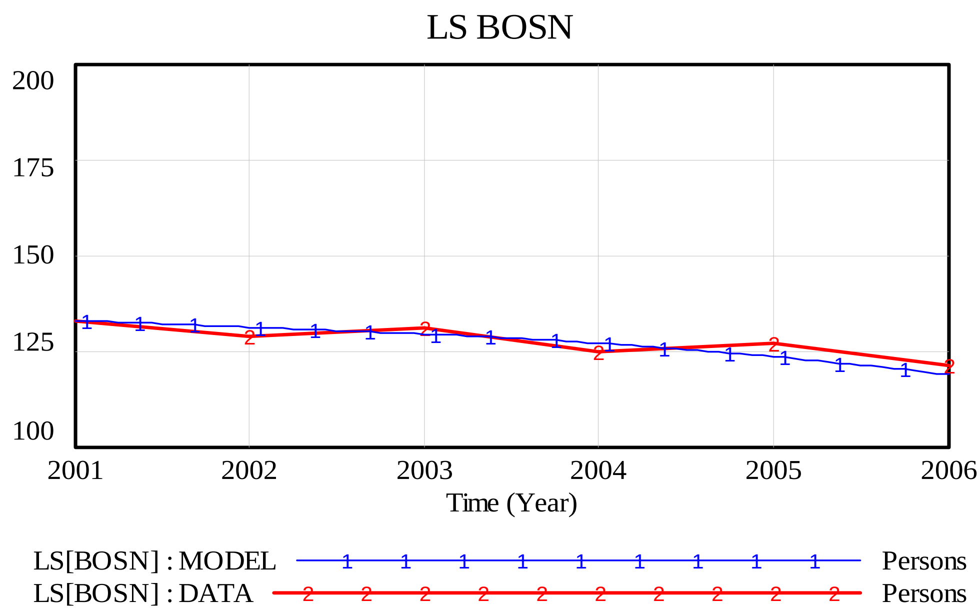

Figure 6: Comparison between Model estimates and Data for LS[BOSN]

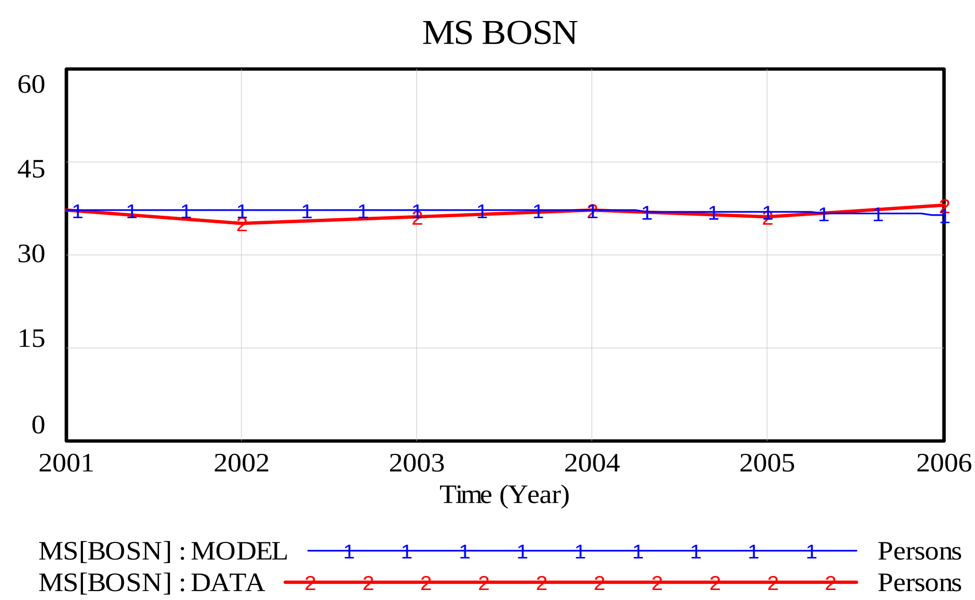

Figure 7: Comparison between Model estimates and Data for MS[BOSN]

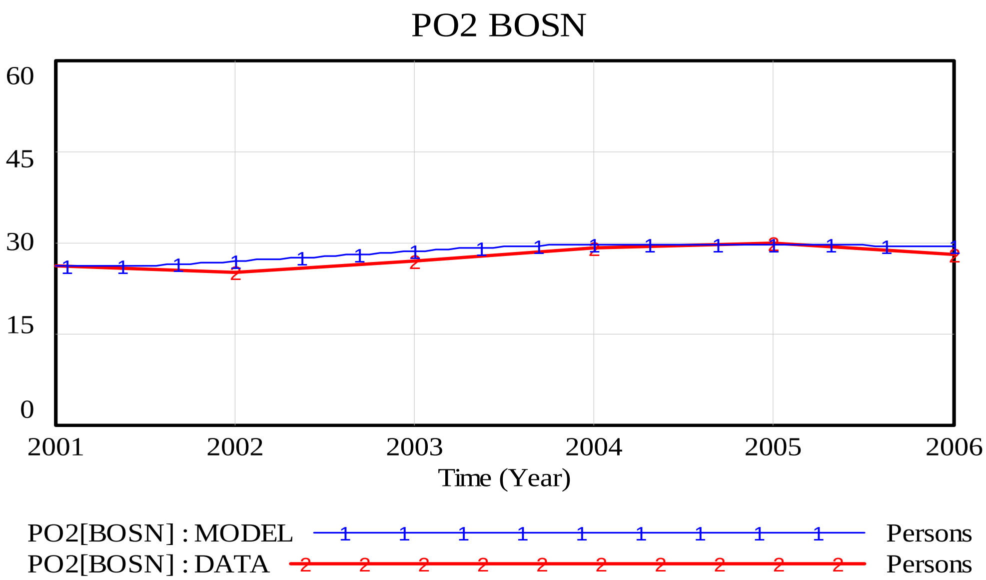

Figure 8: Comparison between Model estimates and Data for PO2[BOSN]

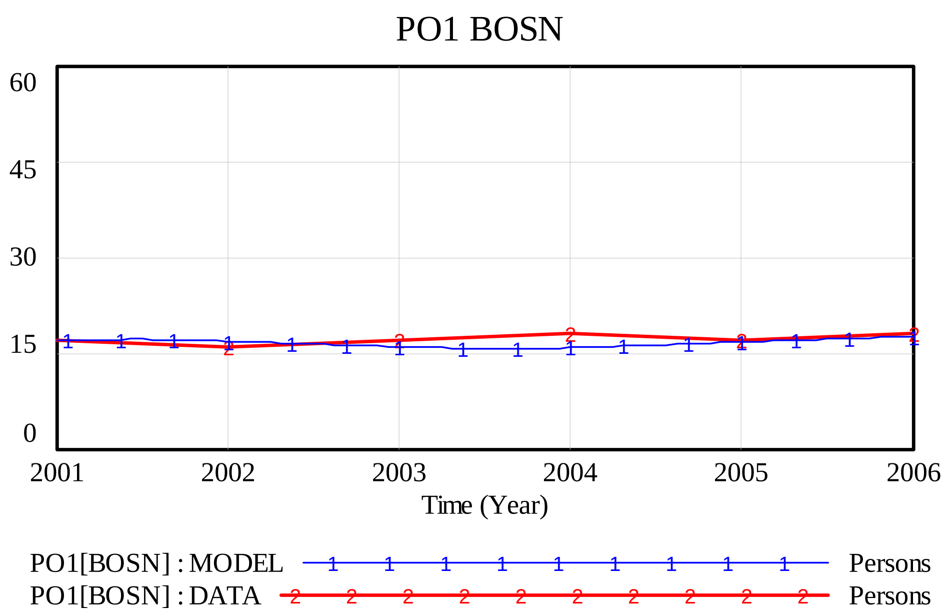

Figure 9: Comparison between Model estimates and Data for PO1[BOSN]

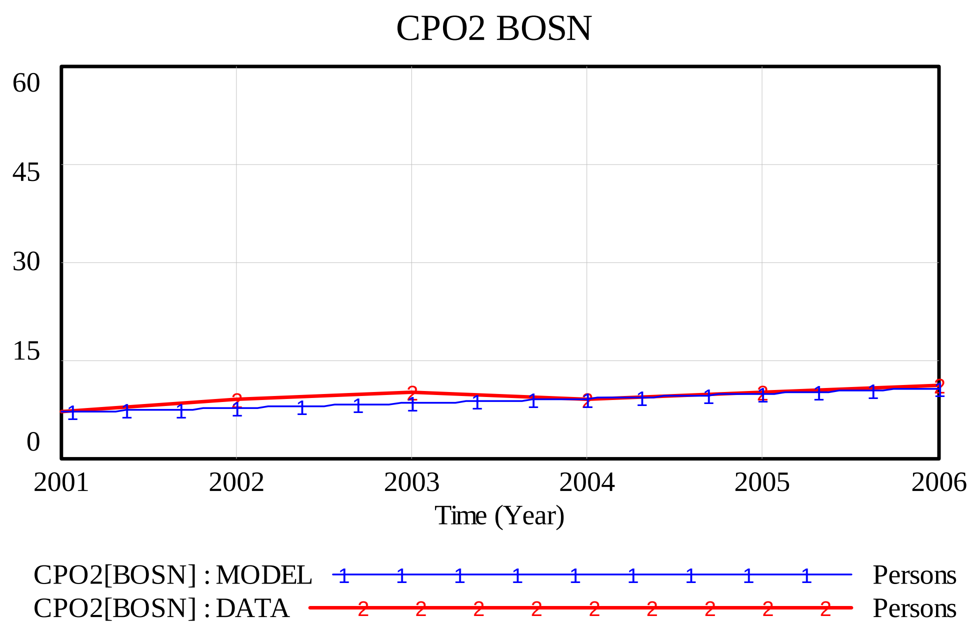

Figure 10: Comparison between Model estimates and Data for CPO2[BOSN]

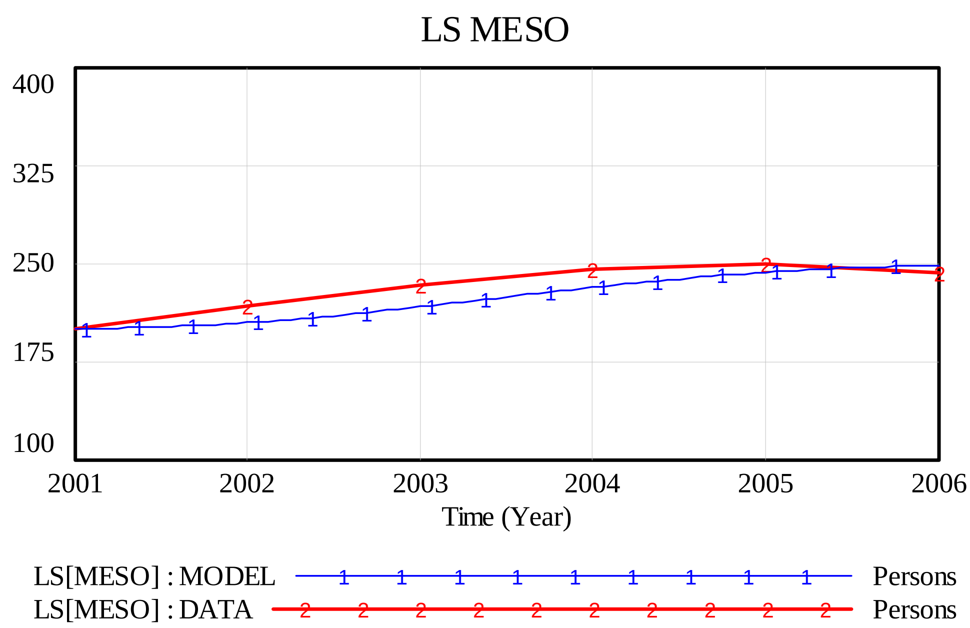

Figure 11: Comparison between Model estimates and Data for LS[MESO]

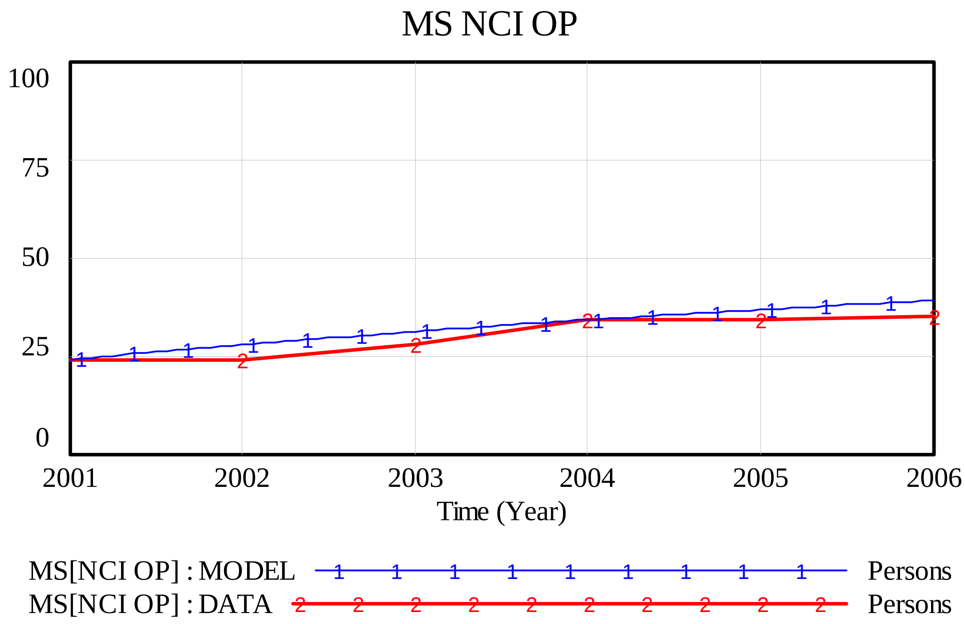

Figure 12: Comparison between Model estimates and Data for MS[NCI OP]

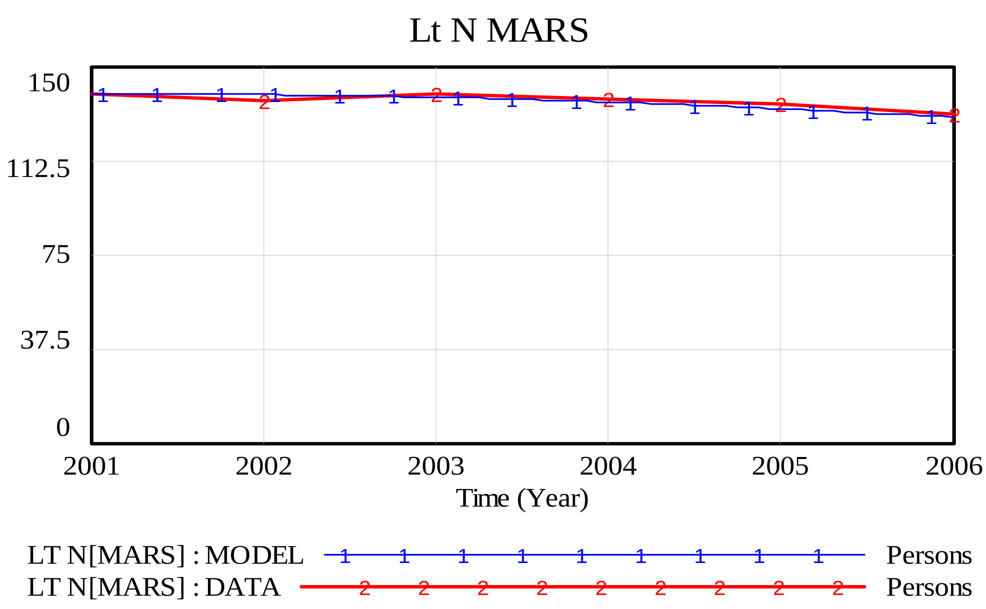

Figure 13: Comparison between Model estimates and Data for Lt N[MARS]

As it can be observed from the results shown in Figure 6 to 13, outcomes of the model in most of the cases are quite consistent with the historical data.

The Root Mean Squared (RMS) error associated with the model estimates in relation to historical data is estimated by using the following formula. As expected, averaged estimated RMS error between model estimates and data is below 5 %.

$$\text{RMS Error (Trade)}^{\text{Rank}} = \sqrt{1/n \sum_{t=2001}^{2006} (\text{Trade}^{\text{Rank}}(t)_{\text{Model}} - \text{Trade}^{\text{Rank}}(t)_{\text{Data}})^2}$$

Where,

RMS Error $(\text{Trade})^{\text{Rank}}$	= Root Mean Squared Error between model estimates and data for different trades
Trade	= NCM and Officers trades such as BOSN, COOK, MARs etc.
Rank	= NCM and Officers ranks such as MS, Lt N, PO2 etc

Flight Simulator

After model testing and verification several experimentations are carried out to analyze the behavior of the model for future years, particularly in response to changes such as reduction in released fractions and promotion times with a nominal percentage. Model is also tested for extended period of time without implementing any changes in the model parameters. The model experimentations indicate promising results. In order to explore the impact of various strategies, a user-friendly interface (Flight Simulator) is also developed that makes the model analysis easier for the model users at NAVRES.

Usefulness of the Model

The usefulness of the model is to aid in designing the human resource management strategies for effectively and economically managing the human resource needs of the NAVRES. As an example, some of the model functions that help management to gain valuable insights into the different strategic issues include:

- Model estimates the yearly enrollment rates of the NCM and the Officers trades under different scenarios such as status-quo situation, increase in demand of certain reservists of various trades, reduction in attrition rates, and increase or decrease in the availability of reservists etc. Users can define the multiple scenarios or single individual scenario and model will estimate the yearly enrollment rates for each defined scenario.

- Model estimates the size of BTL broken down by NCM and Officers trades that can help the management in estimating the resources required at BTL level. Again size of BTL can be estimated under various user defined scenarios.

- Model estimates the size of TES broken down by NCM and Officers trades that can assist in deploying resources for various career progression courses.

These estimates might vary in response to changes such as change in attrition rates, availability of reservists, expanding recruitment or training capacities, and also changes in the number of required positions for various trades at different ranks. Model is capable of estimating the size of TES and BTL in response to such changes that may be implemented in future. The model can assist management to evaluate the impact that decisions related to training and employment may have on the size of the required TES and BTL before they are implemented.

The model is capable of answering many questions, the primary are: estimating the enrollment rates distributed by trades on yearly basis for future years, estimating the size of BTL and TES broken down by trades on yearly basis for future years, and estimating the potential impact on enrollment rates, size of BTL and TES of various scenarios such as change in attrition rate or availability of the reservists.

Future Extensions of the Proposed Model

Based on the model results described above, it is evident that model successfully replicates the basic structure of the NAVRES, and is capable in producing accurate dynamic behavior of the NAVRES from 2001 to 2006. It is recommended that the model be further refined before using it for strategic planning of the NAVRES. These refinements will enhance the accuracy of the model, and will also expand the options for the decision makers to evaluate the impact of various strategies aimed at effectively and economically managing the human resource needs of the NAVRES. These refinements are as follows:

- In estimating the demand of the naval reservists, the existing model does not explicitly consider the impact of seasonal variations. As during the summer season many reservists are available the demand of instructors is relatively higher than any other season. The model considers an adjustment factor that implicitly reflects the effect of seasonal variations. This model should be refined to include explicit consideration of seasonal variations that will improve the accuracy of and reliability of the model results.
- The existing model assumes availability of the reservists for Continuous Service Positions (CSP) and incremental positions varies as they progress in their respective ranks but this variation is assumed to be same for every year. The model considered the availability of reservists based on only 2006 data because data for earlier years was not readily available. This model should be refined to include actual availability of the reservists based on at least five years.
- The existing model assumes attrition or released rates for NCM and Officers are constant. Currently, attrition rates are calibrated based on data from 2001 to 2006, however, attrition rate will vary in future once CSP generation will retire. This model should be refined to incorporate the underlying structure that drives the attrition rate, in addition to considering the aging affect on attrition rates.
- Currently, the existing model does not include transfers from Supplementary List and Regular Force, these may have an influence on the accuracy of estimating the enrollment rates of various occupations. This model should be refined to incorporate the flow of reservists from the Supplementary List of trained reservists and from the Regular Force.
- Calibration of the existing model parameters is based on the data from 2001 to 2006, in some occupations it was observed that provided data is not accurate. Future refinements of the model should investigate data problems.
- The existing model considers a parameter that implicitly represents the effect of instructors, capacity constraints, course duration, and availability on progression rates. This parameter is calibrated based on data from 2001 to 2006. Future refinements of the model should include explicit considerations of these factors which will enhance the accuracy of the model.

The model has been presented to the senior staff of the NAVRES including Commodore and Captains who acknowledged that the model in its existing form will be a very useful management tool for the organization. The model with the proposed refinements, however, will be a more robust tool offering increased accuracy and expanded capability.

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