

**Concept of Operations
For The
COMMUNITY COORDINATED MODELING CENTER**

AF/XOW

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ONR

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Concept of Operations
For The
Community Coordinated Modeling Center

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Committee for Space Weather Chair

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EXECUTIVE SUMMARY

The Community Coordinated Modeling Center (CCMC) was established to aid in the development of models for specifying and forecasting conditions in the space environment. The CCMC fills a long-standing gap between the space weather research community and the operational arms of NOAA and the DoD responsible for providing space weather services to a large customer base. The CCMC concept was initiated in 1998 as a result of efforts by government agencies to enhance space weather research, develop space weather models, and provide a means for more effective transitioning of research models to operations. The CCMC is an essential element of the National Space Weather Program (NSWP) as outlined in its strategic and implementation plans.

The USAF and NOAA have operational responsibility for providing space weather support to their respective customers. Improvements to operational capabilities have been slowed by the lack of a comprehensive process to coordinate basic research and model development, and transition value-added capabilities to operations. The goal of the CCMC is to facilitate the development, validation and test of the largest and most sophisticated space weather models. It will also contain scientific and technical personnel, as well as realistic databases, to efficiently exercise the models and prepare them for transitioning. The CCMC concept recognizes the importance of taking operational requirements into account during the development and testing of a model, rather than at a later stage when it is more difficult to make the necessary modifications.

The CCMC consists of a central site at Goddard Space Flight Center (GSFC) where permanent and temporary staff, as well as visiting scientists, perform the variety of research and model development tasks necessary to achieve the goals of the center. In addition, the CCMC is networked to high performance computing facilities that are used to run the complex space weather models. In addition to performing research and model development, the CCMC undertakes a number of other tasks to support the space weather research and operational communities. The CCMC performs model runs requested by space scientists who will benefit from the insights such models provide in understanding the space weather system and how it responds to solar storms and other natural processes in the space environment. CCMC staff is responsible for developing advanced visualization routines for more accurate interpretation of model results. The CCMC will also explore and exercise various methodologies for assimilating data into space weather models. Validation against standardized metrics will be a key function of the center, which will maintain fair and unbiased records of model performance over a long period of time. The future of end-to-end space weather modeling depends on the ability to efficiently couple successful models in the spatial domains extending from the Sun to Earth. The CCMC will work directly with model developers in exploring methodologies for connecting models in a flexible way, eventually leading to a futuristic patch-panel approach to space weather simulations.

The success of the CCMC depends on active collaboration and coordination among all space weather stakeholders. The CCMC will be well connected to the research community to ensure effective participation by researchers, as well as to enable new scientific

studies and discoveries. Interagency collaboration is essential to achieve the goal of bridging the gap between the research and operations communities. International collaboration will allow for better leveraging of resources with research, observations, and models provided by the worldwide space weather community. Finally, the CCMC will strive to make all output beneficial to educational institutions, and amenable to broad distribution to the general public.

The CCMC will be managed through an interagency steering committee with rotating membership. The Steering Committee will report directly to the Committee for Space Weather of the NSWP. To aid in the management of the center and selection of models, the Steering Committee will select two working groups, also with rotating membership. The Science Working Group will provide advice to the Steering Committee about the current state of knowledge and the availability of new models with potential operational benefits. The Operations Working Group will provide advice on operational requirements and products and help identify models with future operational application.

Models will be selected on the basis of a carefully defined set of criteria, including their potential to meet operational requirements, their scientific value, maturity, robustness, accuracy and validity. CCMC staff will discuss plans and goals for the model with the model developers. The CCMC will also establish a set of exit criteria for the model. Upon meeting the exit criteria, the model will be transitioned to one or both of the Rapid Prototyping Centers operated by the Air Force and NOAA.

An essential element of success for the CCMC is having access to high-speed computers for running sophisticated space weather models. CCMC staff will make use of all available resources, including resident clusters at the CCMC and network connections to super-computer facilities supported by the Department of Defense, NASA, or other agencies.

The CCMC was designed by to be a flexible, long-term solution to the problem of transitioning space weather research models to operations. It is dedicated to ensuring that excellent scientific research is accomplished as models are developed, upgraded and used by CCMC staff and the space science community. Most important is that the CCMC continues to benefit all participating agencies, while at the same time being responsive to the needs of space weather customers and researchers. This Concept of Operations presents an initial plan for how CCMC goals can be achieved. It is intended to be a living document which can be updated as agency priorities change and scientific and technical advances are made.

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Acronym List

Concept of Operations for the Community Coordinated Modeling Center

1.0 GENERAL DESCRIPTION

1.1 Background

The major goal of the National Space Weather Program (NSWP) is to accurately model the energy flow from the Sun and its interaction with the near-Earth space environment, including Earth's upper atmosphere and ionosphere. To achieve this goal, government agencies have jointly developed a center for model development and testing and collaborative exchange of modeling concepts and techniques to improve the state of space weather modeling.

The need for space weather model improvement has been identified as a priority for many years. The major problem is the lack of a comprehensive means to coordinate basic research, model development, and eventual transition of technology into operations. In 1997, a group of scientists under the auspices of a Memorandum of Agreement between Air Force Space Command and the National Aeronautics and Space Administration analyzed the issue via a number of working groups. One group identified the need for a Community Coordinated Modeling Center (CCMC) that would bridge the gap between science and operations. The CCMC would provide an integrated approach to space weather modeling from basic research through rapid prototyping to operational support. Soon after the final results were published, another group of scientists formed an interagency consortium to garner approval for building a non-exclusive, community-accessible computational asset. This asset was to be employed to improve space weather modeling for the domains of the connected Sun-Earth system, couple their outputs, and accurately specify and forecast the energy flow from the Sun to the Earth--essentially fulfilling the NSWP's challenge to accomplish these goals within the next 10 years. The ultimate result will be an improved ability to specify and forecast conditions in space for operational systems sensitive to conditions in those domains. A series of briefings culminated in approval of the initiative by the U. S. Committee for Space Weather. A number of consortium members acquired funding from their respective agencies and they developed an Implementation Plan to secure commitment. This Concept of Operation is a guide on how CCMC will operate for the benefit of science and space weather operations. The CCMC will take advantage of research projects to generate a modeling system that enhances our understanding of the space environment while providing an improved capability to specify and forecast its variability.

This Concept of Operations assumes agency roles and responsibilities as indicated in the CCMC Implementation Plan signed and approved by participating agencies in 1999. As with the Implementation Plan, the roles and responsibilities assigned to agencies represent non-binding guidelines for achieving the overall mission. These guidelines are subject to change at the discretion of any of the participating agencies. The concepts described in this plan are based on collaborative efforts involving representatives of participating agencies committed to the goals outlined here and the future success of the CCMC.

1.2 Purpose

The CCMC aims to satisfy the middle- to long-range science and operational requirements to meet NSWP objectives. In that spirit the mission and goal of the CCMC are as follows:

Mission: To enable, support, and perform research for next generation space science and operational space weather models through an interagency partnership.

Goal: Develop and execute next generation research models in support of the advancement of space sciences and deployment of new operational space weather capabilities

The Community Coordinated Modeling Center was established to enhance basic solar-terrestrial research and to aid in the development of models for specifying and forecasting conditions in the space environment. The main criteria for success of the CCMC are (1) the broad use of CCMC models throughout the scientific community, and (2) the transition of models to operations. The number of runs requested and the number of resulting scientific publications will be indicators of the broad scientific usage of the CCMC. The success of transition to operations will be measured by the number of models that are eventually used operationally and by the estimated value of these models.

The CCMC fills a long-standing gap between the space weather research community and the operational arms of NOAA and the DoD responsible for providing space weather services to a large customer base. At the present time, both NOAA and the DoD have created Rapid Prototyping Centers (RPC), which serve to implement space weather models at their respective operational centers in Boulder, Colorado and Omaha, Nebraska. The CCMC will assemble, validate, and test space weather models that can eventually be transferred to the RPCs to adapt for operational use, as illustrated in Figure 1. The CCMC will have access to computer assets sufficient for the implementation and test of the largest and most sophisticated space weather models. It will also have the scientific and technical personnel, as well as access to realistic databases required to efficiently exercise the models and prepare them for transitioning.

As indicated Figure 1, the CCMC is not meant to be the only means by which space weather models can be made operational. The CCMC will be designed to assist in the implementation of complex and high priority space weather models. Particular emphasis will be placed on those models that can be coupled with others to comprise an end-to-end space weather forecasting system. Selection of models for CCMC will be made on the basis of their potential to contribute to space weather operational forecasting as well as their scientific merit. The CCMC is not intended to be the clearinghouse for all space weather models. Direct submission of individual models from the researcher to the RPCs will remain an option for model developers.

Transitioning Models to Operations

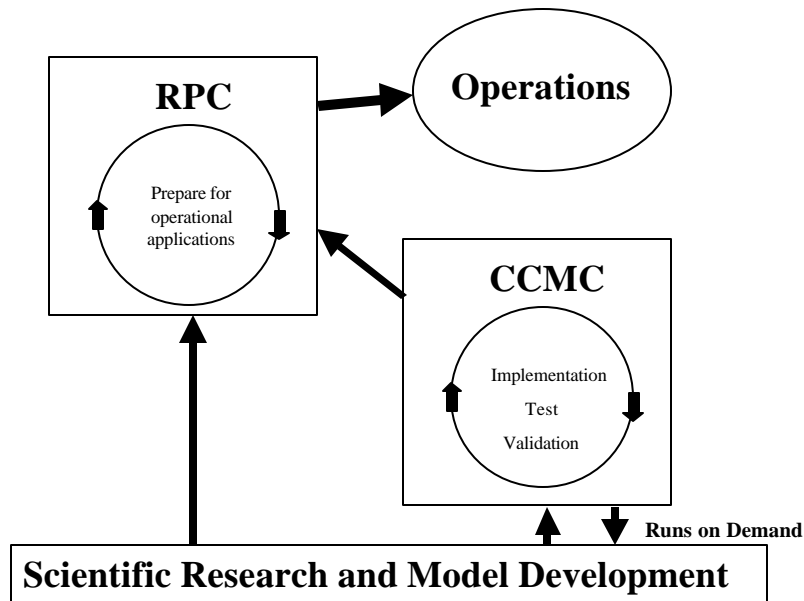


Figure 1. Logical flow for transitioning models from research to operations.

The CCMC will be a valuable resource to aid in the development of space weather models that benefit the operational forecast centers. The CCMC will execute runs-on-demand for space science researchers to assist in the interpretation of data or in the validation of other models. The CCMC staff will work with model developers to couple models to accomplish end-to-end, seamless, space weather modeling. Methods for the assimilation of data into models will be explored to improve the accuracy of space weather forecasts and specifications. A standard set of validation activities based on accepted metrics will be conducted to ensure reliability and accuracy in candidate models. CCMC staff will have the expertise to make recommendations during the model development stages, and will also initiate and participate in scientific studies involving one or more of the models.

Rather than provide the last step in the implementation of a model at the forecast centers, the CCMC is meant to help scientific researchers and model developers design their models with the needs of the forecasters in mind. The CCMC concept recognizes the importance of taking operational requirements into account during the development and testing of a model, rather than at a later stage when it is more difficult to make the necessary modifications. The CCMC and the two RPCs constitute a two-step transitioning process that will continuously ensure compliance and suitability throughout the process.

1.3 CCMC Activities

The CCMC aims to enhance scientific understanding, aid researchers and model developers, and facilitate the transitioning of validated models to the RPCs. Included in these

goals is the direct support of scientific research, as well as support of space flight mission design and operation. Model runs at the CCMC will enhance the value of present and future space-based and ground-based programs. The CCMC is not meant to be a general purpose computing facility. Models will be exercised, tested, and validated in preparation for transfer to the RPCs. Research conducted at the CCMC will be targeted toward those activities improving the ability to specify and forecast space weather. Results of CCMC-enabled research will be published in refereed space physics journals. System resources will be allocated to accommodate model studies, scientific runs for particular events, execution of runs on request, and batch processing for large numerical studies. CCMC scientists will develop an overall visualization architecture that will allow researchers to view their results on line. Data sets will be distributed electronically as well. Source code release will be handled on a case-by-case basis according to agreements made with code originators. A user interface will be developed to facilitate researcher requests for model runs and access to results. Researchers will be encouraged to offer models that couple various elements of the Sun-Earth system. CCMC staff will work with model developers as necessary to aid in the coupling of models. Implementing a spine architecture where model components are interchangeable is a longer-term goal. Testing of models using standardized metrics will ensure that improvements in model capabilities are accurately tracked.

1.3.1 Model Implementation and Development

As part of the acceptance of a model, the CCMC staff will develop a plan for its implementation, testing, and validation. A specific set of metrics for the model will be adopted as a measure of progress in model development. The staff will also determine which space weather products the model will support, and develop the algorithms necessary to generate the products from the model output. These planning activities will be undertaken in consultation with representatives from the relevant RPCs.

The model testing process will be cyclical, where the model is run using a set of standardized inputs and the results evaluated against standard benchmarks. During the testing procedure, the CCMC staff will collaborate with model developers to modify and upgrade the model as necessary, and investigate opportunities for coupling the model to others. In consultation with the model providers, staff members will identify opportunities to assimilate other data sources into the model and develop visualization software to display model output.

Scientific research activities will be integrated into the testing process, and form a basis for model validations. Whenever possible, the models will be run in a way that produces meaningful scientific results for use by researchers from both within and outside of the CCMC. Rules of the road will be developed to govern the way in which model output is used in scientific research.

Models will be evaluated periodically to assess their readiness for transitioning to one of the Rapid Prototyping Centers. Among the factors to be considered in evaluating readiness will be the model's demonstrated accuracy, robustness, and validity, as well as the

value the product will provide for space weather forecasting. Models that are transitioned to the RPCs may still be kept at the CCMC for use in scientific studies, and for further upgrading and comparison with other similar models.

1.3.2 Runs on Request

Outside scientists will be kept informed of CCMC modeling activities through the CCMC web site. Investigators interested in running a model for a particular event, or case study, may request a dedicated run, either through the CCMC web site, or by contacting CCMC staff directly. These runs will be executed on a non-interference basis and the model results will be made publicly available. During the initial phase of operation of a model submitted to the CCMC, the outputs of the model will be regarded as “key parameters”, in the sense that they are preliminary and are subject to verification by the model developers or CCMC staff before being used to reach sound scientific conclusions. Users of these results will be encouraged to collaborate with the model originators before publishing results based on this output.

Initial input, output, and visualization interfaces for runs-on-request will be relatively simple. As experience with this mode of operation improves, the CCMC staff will implement more comprehensive interfaces that offer users more flexibility in terms of input, output, and customized visualization. For example, future capabilities will include allowing for different run lengths, interactive choice of initial grid size and spacing, choice of conductance model, a broader suite of models available, and the option to couple specific models at users’ request.

The ultimate aim of runs-on-request is not solely to provide researchers with a resource for conducting scientific studies of specific events. Runs-on-request also provide a context within which models can be exercised over a broad range of conditions. Also, they provide an effective means to introduce the model to other researchers and expose the model’s strengths and weaknesses. For these activities to be of maximum benefit, the CCMC must establish appropriate quality control mechanisms and guidelines for configuration control as new model versions are implemented. Specific guidelines will be established by the CCMC as the staff acquires more experience in the production and use of model output. The ground rules for running models, displaying output, and distributing results to users will be mutually agreed upon between CCMC staff and the model developers.

1.3.3 Visualization

Providing accurate and illuminating model output visualization is an extremely important function of the CCMC because it can aid researchers, model developers, operational staff, and educators. The CCMC will implement a variety of visualization tools to enable users to work with the output of requested model runs. The software used for the visualization tools may include a number of commercial and non-commercial products. Currently, visualization tools have been implemented in the Interactive Data Language (IDL) and in OpenDX. IDL is a commercial product while OpenDX is free and open-source. Visuali-

zation tools may be made directly available to users or may be used over the web interface to the CCMC as appropriate. As technology in this area is proceeding rapidly, the CCMC staff will ensure that visualization techniques at the CCMC continue to make best possible use of state-of-the-art hardware and software.

1.3.4 Data Input and Assimilation

CCMC will manage incoming (processed) data streams for assimilation into CCMC models. For this purpose, the staff will, in coordination with the science and operations working groups, establish and maintain contact with appropriate data providers, such as the National Space Science Data Center (NSSDC).

The CCMC staff will provide free and open access to all science-quality model output generated at the CCMC. Access to the data will be primarily through the CCMC web site. The staff will attempt to convert the results from model output into easily readable formats. Access to data not generated at the CCMC will be provided if possible, if consistent with the CCMC mission, and only with the permission of the original data provider. The CCMC staff will strive to provide long-term archiving of selected model runs, in collaboration with the NSSDC at GSFC and other data centers.

Future capabilities to be implemented at the CCMC will allow users to specify spacecraft location and time, either for enabling the spacecraft data to be used as input to CCMC models, or so that model output can be easily compared with measurements made by the spacecraft. The CCMC will also work with data providers to add quality-checking procedures on data prior to their use as input to models.

1.3.5 Validation and Metrics

The term “model validation” refers to a broad effort to test and exercise models for a wide range of circumstances and applications. CCMC efforts at validation will involve a variety of tests and studies carried out by CCMC personnel. The totality of information accumulated in these studies is intended to help evaluate the scientific validity and potential operational value of a model and when it may be ready for transition to a rapid prototyping center.

A metric is a single number that is used to indicate the agreement between different models or algorithms and observations. It may also provide a quantitative index of the progress of a field of research. A metric provides an objective, though narrow, measure of model performance, and it can be applied with no prejudice to a large number of models.

Initially, the CCMC will adopt metrics developed for assessing progress in the NSWP. These are simple metrics that can be generated routinely by running models for pre-selected intervals when observations are known to be available. The space weather metrics are not meant to be definitive indicators of the advancement of knowledge; they are designed to demonstrate gradual progress in predictive capabilities over a long period of

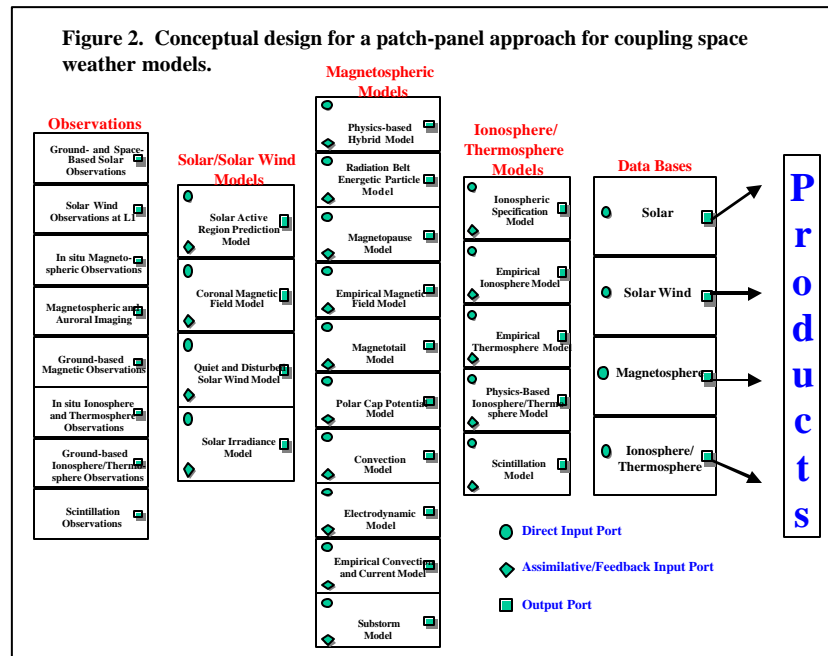
time. The CCMC will be the unbiased broker in generating and archiving metrics for as many models as possible, resources permitting.

In the future, the CCMC may routinely incorporate other metrics into the output stream of models running at the center. Other types of metrics include those used to evaluate accuracy in specific operational areas or for specific space weather customers. A more sophisticated suite of metrics to determine progress in basic understanding of the space weather system may also be incorporated and evaluated on a regular basis.

When a model is first accepted at the CCMC, CCMC staff will work with an operations working group and the operational agencies to develop a validation plan, if none exists already for this class of models. The plan will define the metrics to be used in the validation, the rate at which the model will be tested against the metrics, and the input that will be used in driving the model during test runs.

1.3.6 Model Coupling

One of the main goals of the CCMC is to aid in the assembly of a suite of space weather models that can be used to specify and forecast the entire space weather system from the Earth to the Sun. Historically, models have been developed that apply only to limited portions of the entire system. Only recently have MHD models been developed to simulate the entire system including the many spatial and temporal scales necessary to account for all the physical processes that occur. An alternative approach is to couple the various specialized models that have been developed over the years. The ultimate goal of such a system is illustrated in Figure 2. Each model at the CCMC would have standardized input and output ports that would allow it to be coupled to any other model, as well as to assimilate different types of data streams. Although the implementation of such a system is extremely complex, the flexibility and versatility provided by the patch-panel, or plug-and-play approach, will be a tremendous aid for validating and optimizing space weather simulations.



In spite of the advantages of this approach to space weather modeling, there are unavoidable difficulties. The CCMC is initially concentrating resources on the important tasks of testing and validating existing models, rather than an implementing a full-scale adaptation of the patch-panel approach. Also, there are currently no accepted rules for constructing standardized interfaces among models, and some degree of experimentation should be conducted before these common interfaces are finalized. Furthermore, the feedback loops between coupled models often entail new physics, like coupled oscillations and instabilities, that need to be understood before individual models can be successfully linked. Finally, it is not clear that coupled models currently offer the best solution for space weather problems, especially since the capabilities of individual codes continue to improve.

Because of these difficulties, the CCMC will embark on a multi-pronged approach for space weather modeling. Progress in these areas will require the CCMC to work closely with modelers and researchers and take advantage of advancements as occur. The four primary activities are:

1. Incorporate models for specific domains and begin experimenting with simple model-coupling techniques, such as those that can be applied to models with isolated driving interfaces.
2. Incorporate end-to-end models of the space weather system that run as stand-alone codes.
3. Experiment with coupling of models with feedback interfaces and data assimilation input capabilities.
4. Establish plug-and-play interfaces that can be incorporated in any space weather model to implement the patch panel modeling system.

It is not meant for these four activities to be conducted in succession. Resources permitting, the CCMC staff may undertake all four of these activities simultaneously. However, the division of labor for these activities will be such that most rapid progress will be achieved for the higher priority activities before increasing the time and effort expended on the long-term goals. The CCMC Steering Committee, in conjunction with science and operations working groups, will review progress in these areas on an annual basis to ensure the appropriate balance of effort among the four activities.

1.3.7 Annual Progress Report and Program Plan

The CCMC will produce an Annual Progress Report and Program Plan for review by the CCMC Steering Committee. The report will include all activities undertaken at the CCMC, including models implemented, models run, models coupled, models transitioned to the RPC, and research conducted by the CCMC staff. Any activity considered outside the primary functions of the CCMC will be recommended for outside funding.

1.4 CCMC Programmatic

As an element of the NSW, the CCMC is linked to the larger space weather research and operations community, both nationally and globally. In addition to the modeling activities described above, the CCMC will conduct activities to maintain communications with, and foster coordination with, all space weather stakeholders. This section identifies those activities necessary to enhance the roles the CCMC will play in improving the understanding of space weather and in making space weather products more valuable to customers and the general public.

1.4.1 Interactions with the Space Weather Community

In the context of the CCMC, the space weather community consists of three parts: 1) those who develop codes of interest to CCMC for its operational and scientific users, 2) the CCMC personnel who act as a bridge between code developers and prospective code users, and 3) the potential research and operational users of CCMC models.

For the code developers, CCMC provides a means to make models more visible, more widely used, and better appreciated by the larger scientific community. To be most beneficial to code developers, there must be a mutually agreeable understanding of what the CCMC will do with the code and how it will be used. Issues regarding source code accessibility, configuration control, and dissemination of results must be agreed upon in advance of the code being accepted into the CCMC. Although general “Rules of the Road” regarding the use of model results will be developed, CCMC staff will work with model providers on an individual basis to determine more specific guidelines for activities related to each model. In some cases, CCMC will agree to retain the integrity of donated source codes, treating the code as a “black box” with standardized input and output. In other cases, CCMC staff will have access to the source code and will make modifications as necessary. The staff will work with code developers to establish a communication process that will effectively notify developers when changes to the source code have been made.

For research and operational users of CCMC models and model output, the CCMC staff will maintain an up-to-date web site containing information about all codes. Output from runs on request will be archived and made available on-line to all scientific and operational users. The output will be identified with the requestor’s name so that he/she can be notified when the output is to be used for other studies. When possible, the staff will help users by modifying visualization software to customize displays for specific purposes. The staff will also publicize results of metrics and validation runs of models so operational and scientific users can better evaluate the progress being made in code assessment. The CCMC staff will work with operational forecasters and space weather customers either directly or indirectly through the military and civilian Rapid Prototyping Centers. Staff members will offer suggestions for new space weather products that will enhance service to space weather customers, and they will develop visual displays that will better elucidate space weather processes to non-scientific users.

For CCMC staff, the CCMC will provide an excellent venue to conduct individual research studies, while at the same time providing the conduit for successful research col-

laborations with code developers. In particular, the CCMC represents an excellent research environment for young scientists who will benefit from the exposure to many different types of models and from the many possibilities for collaborative studies that will arise during the course of CCMC activities. Because of the end-to-end nature of space weather modeling, CCMC staff will be exposed to multi-disciplinary research that crosses the boundaries between space weather domains.

1.4.2 Interagency Collaboration

Interagency collaboration in the CCMC is a critical element of the Center's success in providing a conduit from research to operations. In the execution of CCMC tasks, the CCMC will support a variety of agency missions. Currently, the programs that will most benefit from CCMC activities are the multi-agency NSWP, NSF's CEDAR, GEM, and SHINE programs, and NASA's Living With a Star program. In addition, CCMC supports a variety of DoD programs and missions whose ultimate goal is to provide space weather information to defense systems sensitive to conditions in the space environment. In particular, the CCMC helps fill the model development and transitioning tasks identified by the National Security Space Architect study on space weather and the resulting transition plan. The CCMC also supports NOAA's and the DoD's space environment prediction functions by providing near-operational models to the two Rapid Prototyping Centers.

Responsiveness to agency mission requirements will be assured primarily through agency representation on the CCMC Steering Committee. Agency representatives will also serve on both science and operation working groups as needed. Continued participation will be ensured through this active oversight process which will monitor CCMC's support for critical programs, the rate at which models are transitioned, and the quality and value of space weather products developed.

The growth of the CCMC will depend on the continuation and augmentation of agency support. This will evolve as a natural consequence of the CCMC's success in providing services that meet agency requirements. There are a variety of means for agency support for the CCMC other than direct funding for staff and computer resources. The CCMC will benefit from visiting students and scientists supported as part of grants awarded by funding agencies. The CCMC will also take advantage of opportunities to involve post-doctoral researchers through programs such as CEDAR, GEM, and SHINE, or through support from the National Research Council. When feasible, the CCMC will explore student participation through local universities. The agency representatives on the CCMC Steering Committee will help identify funding opportunities for the CCMC in future research announcements and proposal solicitations. When appropriate, these opportunities may be explicitly identified in the announcements. The CCMC Steering Committee will also explore possibilities for in-kind contributions from federal agencies to enhance the Center's infrastructure and staff.

1.4.3 International Participation

Access to CCMC services will be open to members of the international science community. As international participation increases, the CCMC will provide the means for more direct representation from global partners, including participation on the working groups and steering committee. Whenever possible, CCMC representatives will attend international workshops and conferences to report the status of CCMC activities and describe opportunities for international collaboration.

The CCMC Steering Committee will deal with issues related to the International Trafficking in Arms Regulations as they arise. Every effort will be made to maintain active and open collaboration with the international science community in compliance with present and future federal regulations.

1.4.4 Education and Public Outreach

The CCMC is one element of a much larger effort to train the next generation of scientists and engineers in space weather, and to educate the general public about the importance and impacts of space weather effects. It is also conceivable that the CCMC will provide a means to educate both military and civilian operational forecasters in the use of modern space weather models. Possible strategies for such efforts include organizing conferences, international schools for space weather studies, and providing runs-on-request for students. The CCMC web site will be used to publicize progress in space weather modeling efforts. Graphics and visualization techniques will be exploited for displaying CCMC output in appealing formats that can be used in classrooms or for public dissemination, for example, animated displays of terrestrial responses to space weather storms for use in local TV weather reports.

2.0 CCMC ORGANIZATION

The organizational structure for the CCMC is indicated in Figure 3. The CCMC is an integral element of the NSWP. Its role in the NSWP is described in the Implementation Plan (The National Space Weather Program, The Implementation Plan, 2nd Edition, July 2000, FCM-P31-2000, Washington DC). The CCMC is managed by the CCMC Steering Committee, which reports to the Committee for Space Weather. The NSWP Program Council provides high-level agency oversight for the nation's space weather activities. The Steering Committee will have representatives from government agencies only, but scientific, technical, and operational guidance will be obtained through two working groups. Day-to-day management of the CCMC facility at Goddard Space Flight Center is the responsibility of the CCMC Director. A more detailed description of the roles and responsibilities of these organizational elements follows.

2.1 Steering Committee

The CCMC Steering Committee will consist of representatives from NASA, Air Force Director of Weather, the National Science Foundation (NSF), the Air Force Research Laboratory (AFRL), the National Oceanic and Atmospheric Administration Space Envi-

ronment Center (NOAA/SEC), the Air Force Space and Missile Systems Center (SMC), the Air Force Office of Scientific Research (AFOSR) and the Office of Naval Research (ONR), as well as the CCMC Director. Additional members may be added at any time as appropriate with full concurrence from all members. The Steering Committee will be co-chaired by members from two different agencies, preferably representing both the research and operations communities. Co-chairs will be selected by the chairs of the Committee for Space Weather and will serve two-year terms. Chairs are responsible for scheduling meetings and teleconferences, preparing agendas, coordinating with working groups, and arbitrating disputes. The Steering Committee will meet twice per year. Teleconferences may be called at any time by request of any member.

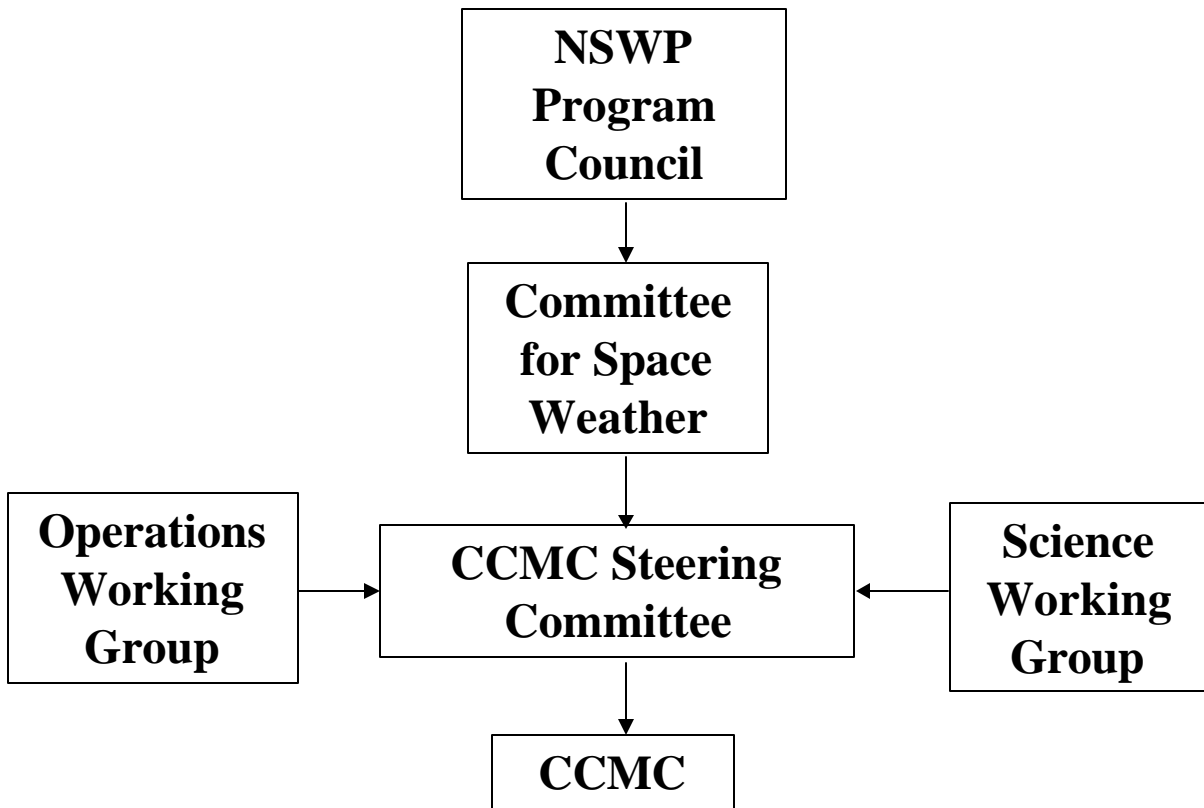


Figure 3. Management structure for the CCMC.

Most decisions of the Steering Committee will be made on the basis of a simple majority vote, with each member allowed one vote. Split decisions will be deferred to the Committee for Space Weather. All members have veto power over decisions that have financial impact on their respective agencies.

The Steering Committee is responsible for ensuring that the overall goals and mission of the CCMC are accomplished. Responsibilities include setting procedures for selection of models, setting criteria for model acceptance and exit, determining standards for configuration control and documentation, interfacing with science and operations working groups, and representing CCMC interests within member agencies. The Steering Committee is responsible for ensuring effective fusion of operational and scientific requirements for CCMC tasking. The Steering Committee will strive to maintain a balance between CCMC tasking and available resources. The committee will oversee the CCMC web site and implement procedures and schedules for timely updating of information for the scientific and operational space weather communities. Members will attend meetings and workshops to communicate CCMC activities to all space weather stakeholders.

The CCMC Steering Committee will provide general oversight of the activities conducted at the CCMC through the CCMC Director at GSFC. The CCMC Steering Committee will establish general guidelines to develop space weather capabilities as well as test, validate, and couple models to satisfy the operational and scientific needs. The Steering Committee will set metrics and standards for evaluating models based on guidance from the NSWP.

The Steering Committee is responsible for leveraging available resources to accomplish CCMC goals. Since the CCMC requires participation from a broad segment of the space weather research and operations community, interagency support for this participation is essential. Members will represent CCMC interests within their agencies to ensure continued support from those agencies through appropriate funding mechanisms.

The Steering Committee will select members of the science and operations communities to establish a Science Working Group (SWG) and Operations Working Group (OWG). These members, if they are available to participate, will serve in an advisory capacity to help in identifying operational requirements, potential models for CCMC implementation and in evaluating model performance in a research and operational setting. In consultation with the SWG and OWG, the Steering Committee will establish criteria for prioritization of CCMC activities and will synthesize operational and science needs into a prioritized list that will govern the CCMC operation. The Steering Committee will solicit input from the Working Groups as needed, and recommend specific actions or studies to be undertaken by the Working Groups. The Steering Committee, in conjunction with the SWG and OWG, will review the Annual Report and Program Plan prepared by the CCMC Director. The outcome of this review will be used to provide guidance to the CCMC Director regarding future activities and priorities during the next year.

2.2 Working Groups

Effective functioning of the CCMC will be ensured through the participation of two Working Groups, one for scientific research (SWG) and one for operations (OWG). Working Group members represent specific points of contact in communications between the CCMC Steering Committee and the operations and research communities. Members of the Working Groups are selected by the Steering Committee on an informal basis.

Most Working Group meetings will occur in conjunction with larger meetings, conferences, and workshops, and attendance will be open to all members of the research and operations communities, typically every 6 months.

2.2.1 Science Working Group

The primary functions of the SWG are to recommend models to enter the CCMC and to advise the Steering Committee on the operation of the CCMC for maximum benefit to the science community. Because the broad use of the CCMC by the science community is critical for its success, the SWG will serve as an important liaison between the Steering Committee and the scientists. The SWG will provide insight for model development and scientific research addressing CCMC issues. The SWG will identify specific activities to be undertaken in the development of models, the use of data, the merging of models, and scientific research conducted with the models. Members will continually monitor model development in the research community and propose models for implementation at the CCMC. Members will also monitor basic scientific research for new approaches to modeling and meeting operational goals. The SWG will assist the CCMC in prioritizing and evaluating models, and will encourage the use of the CCMC and CCMC output by the scientific community. The SWG members will be liaisons to the scientific community on CCMC actions/progress, reporting on present and future modeling activities at the center. SWG members may solicit input from other members of the community as needed. Members of the SWG will usually be active participants in the GEM, CEDAR, SHINE, and LWS programs and may also include representatives from NSF, AFRL, NASA, and AFOSR.

2.2.2 Operations Working Group

The OWG will have responsibility for the prioritization of operational needs and will determine and prioritize operational requirements. The OWG will keep the Steering Committee informed about the needs of the operational and user communities. The OWG will make recommendations about the types of models to be implemented, the types of data available, the kinds of visualization techniques to be used, and the products expected in conjunction with the various models. The members will provide data and information about the operational resources that are currently available. The OWG will evaluate the current state of operational models and prioritize or recommend capabilities to be developed to the Steering Committee. The OWG will define the outputs for the various models that are useful to operations. The OWG will monitor what the CCMC is generating and will maintain metrics on delivered capabilities. Members will recommend research priorities for space weather funding. Members of the OWG may include, in particular, representatives from SMC, NOAA, AF/XOW, AFSPC, AFWA, NASA and the RPCs.

2.3 CCMC Staff

The CCMC is located at NASA Goddard Space Flight Center (GSFC) in a dedicated facility. The CCMC houses staff consisting of NASA civil servants, contractors, postdoctoral fellows, and visitors engaged in CCMC activities. The CCMC facilitates access to

computational resources via a suitable fast network connection. In this function, the center manages computational runs performed as part of the CCMC process on these resources, and assigns resources as needed and available.

CCMC staff will manage the workstation-level front-end computers located at the center itself. CCMC front-end computers act as development tools, web servers, and pass-through facility to access CCMC computational assets.

The primary functions of the CCMC staff will be to facilitate the broad usage of the CCMC models by scientists and to conduct model validation activities. The CCMC staff will engage in scientific research as required to support the CCMC mission. Potential research areas include: 1) improving physical understanding with the goal of developing better space weather models, and 2) exploring new computational techniques for combining models developed in the research community.

A GSFC civil service scientist will head the CCMC. His/her responsibilities are to represent the center, to oversee the center staff, to manage day-to-day operations, to interact with model providers, and to implement Steering Committee policies. As a member of the Steering Committee, the Director will participate in Steering Committee activities. The Director will be responsible for preparing the Annual Report and Program Plan for review by the CCMC Steering Committee.

Postdoctoral fellows will be selected when possible to participate in model development and other research activities at the CCMC. The goal of the CCMC is to have three such resident postdoctoral positions to provide scientific expertise in all space weather domains. Postdoctoral positions will be for three years with new selections made each year. This will ensure various levels of experience among the three postdoctoral fellows, and sufficient overlap between consecutive positions. Support for postdoctoral fellows will be provided through a combination of funds from NSF, AFOSR, and NASA. Postdoctoral selections will be made by majority consensus of the Steering Committee.

The postdoctoral fellows at the CCMC will primarily conduct scientific research using the CCMC models. However, they will also work closely with CCMC staff in the testing and validation of models. They will aid in algorithm development and contribute to efforts to couple models. Postdoctoral fellows will act as liaisons between the CCMC and the modeling community.

Students and Visiting Scientists will be admitted to the CCMC upon approval of the Steering Committee. As opposed to postdoctoral fellows, Students and Visiting Scientists will be expected to have outside support for their CCMC activities. In general, they will work on specific models, conducting scientific research and developing models.

The CCMC strongly encourages visits to the CCMC facility at GSFC. The CCMC will provide for such visitor's access to computers as required and commensurate with security regulations. It is envisioned that such visits fall into two categories. First, modelers who wish to contribute their model and have been selected by the Steering Committee to do so are invited to spend time at the CCMC to work on model integration with CCMC

staff. A temporary residence at the CCMC would allow a contributor to directly access CCMC computational assets, provided the visitor has been cleared appropriately. Second, visits for scientific purposes, or to test models for operational use are also welcome. Here a temporary residence would allow a visitor access to a larger host of simulations, as well as to work with CCMC staff to design runs for specific scientific purposes. It is planned that such science activities are part of the CCMC process, and that results will be used to validate CCMC models.

3.0 CCMC Model Selection

3.1 Model Selection Procedures

In general, there will be two conduits by which models may be brought into the CCMC:

- Modelers wishing to implement their models at the CCMC may contact Steering Committee or Working Group members directly.
- Modelers may be invited by Steering Committee or Working Group members to submit their models.

In either case, the Steering Committee will make the final decision on whether to admit the model.

The Steering Committee is responsible for establishing fair and effective means for selecting models to be implemented at the CCMC. The Steering Committee will actively maintain communications with both the research and operations community, through the Working Groups, to ensure that operational needs are addressed and that research models with potential benefit to operations are brought into the CCMC. The Steering Committee will review the status of models currently running at the CCMC and assess other models for future implementation every 6 months. Both currently running models and prospective models will be evaluated on a set of criteria as described in section 3.2.

Investigators wishing to make use of CCMC resources and to have their models tested and validated for operational use will be asked to submit to CCMC a brief document including a description of the model, the scope of effort required to implement the model, the potential impact on space weather operations, and the likelihood of success. The specific review criteria by which the models are evaluated will be determined by the Steering Committee. The CCMC does not provide funding for model implementation, but will work with model developers to identify strategies for acquiring such funding if necessary. If appropriate, modelers may request direct access to the CCMC computers for model implementation and testing, but will be expected to satisfy all required security checks. NASA GSFC can entertain modelers with these requirements for a period of time negotiated between the modeler and the CCMC Director.

Less complex models that will not consume a significant fraction of CCMC resources may be implemented at any time at the discretion of the CCMC Director. In this case, modelers will not be provided access to the CCMC computers, but will provide source code and instructions so that CCMC staff will be able to run the model as needed. The

Director of the CCMC will provide a list of these models to the Steering Committee on an annual basis.

Models may also be installed at the CCMC by visiting scientists. The Steering Committee will review requests from scientists wishing to come to the CCMC and use the center for an extended period of time at their own cost. Models brought by visiting scientists will be run on a non-interference basis.

Once a model has been selected for implementation at the CCMC, the CCMC staff will identify the activities necessary to make the model available for community use and in some cases eventually ready for transitioning to operations. With input from the model developer as well as the SWG and OWG (see below), the Steering Committee will review the test and validation plan for each model running at the CCMC. The Steering Committee will identify any special requirements, such as the type of data to be assimilated in the model, or other models to which the model may be coupled. The Steering Committee will also determine which are the most important exit criteria to be satisfied and possible ways to enhance the output of the model for operational use.

3.2 Model Acceptance Criteria

The mission of the CCMC requires the implementation and testing of models developed by the research community. Judicious allocation of CCMC resources depends on the careful selection of models to be brought into the center.

The acceptance criteria represent a balance between the anticipated likelihood that the new model will advance the research and operational goals of the CCMC. Other considerations are costs associated with bringing the model into the CCMC and having it broadly available for community use. Although all models will be unique in many respects and no single set of criteria can be applied uniformly, the primary considerations used to evaluate the suitability of new models for the CCMC are relevance, compatibility, and reliability. Models proposed for acceptance in the CCMC will be evaluated by the Science and Operations Working Groups, with recommendations then made to the CCMC Steering Committee.

Relevance

Models must be relevant to the research and operational goals of the NSWP.

Compatibility

Models must be compatible with the hardware, software, and data resources available to the CCMC. The CCMC will provide information about hardware, software, and visualization resources available through the CCMC web site to help a user infer the suitability of the CCMC resources for his/her model via the web page. The CCMC will also provide information on the data and model resources available for model use.

Modelers will provide information about resources required for the model to run successfully and generate output for later retrieval and exploitation. This will include required CPU usage, RAM usage, storage required per time step, disk storage, visualization tools used, required network connectivity, and any verification that has been performed and the

results. This might include publications where the results have been documented and any additional special considerations that may be required.

Reliability and Range of Validity

The model must run reliably using data available at the CCMC, which conform to the model's range of validity. The model should operate without unanticipated interruptions, and if possible, the model should flag suspect output.

Model input requirements such as data type, format, time resolution, and treatment of data starved conditions must be provided. Model output format including units, resolution and known limitations should also be provided. In order to avoid inappropriate model use, developers should also explicitly specify the range of validity for input parameters and input data streams.

Documentation

In addition to relevance, compatibility and reliability, model selection will be based on the level of model documentation. Emphasis will be placed on source code documentation, and legibility. It is desirable that the model be documented internally (not just the part with which the CCMC will interface). Larger models should be modular to support model modification as well as to allow output from intermediate stages to be extracted for other research and/or operational applications.

The CCMC will work with modelers to produce a model development plan. This will include a description of the model/data comparisons, the comparisons that could be made, and the suggested steps that could be taken to improve the reliability and the accuracy while in the CCMC. This plan should also include an estimate of the staff support required to implement the model and the time required to adequately train the staff in the maintenance and use of the model and to properly interpret the model results. Researchers will be asked to analyze and report their results to the CCMC at GSFC.

Participation

The extent of participation by modelers in CCMC activities will depend on the resources available for such participation. The opportunity to leverage CCMC resources with support from other sources will be an important consideration in setting the level of participation. Among the possible sources of such support are:

- Modelers with active awards with federal agencies may ask for supplements or additional funds, as appropriate, for CCMC model implementation activities.
- Modelers may submit proposals requesting resources that would enable them to implement models at the center.
- Modelers may request permission to visit the CCMC for a period of time to work with CCMC staff in the development and testing of the model.
- Modelers may send students, postdoctoral fellows, or other visiting scientists to the CCMC to participate in model testing and evaluation.

3.3 Model Acceptance Considerations

The CCMC web site will contain a questionnaire that will aid investigators in submitting requests to the Steering Committee. The web site will also contain information about current operational space weather requirements and gaps in modeling capabilities at the CCMC. Following is an example of the types of questions that will be considered in model selection. The CCMC Steering Committee will review these considerations for candidate models in consultation with the two Working Groups.

- Does the model have the potential to contribute to operational requirements of space weather forecasters?
- How would this model add to, improve, or complement current capabilities?
- Is the model based on sound physical principles?
- What are the spatial and temporal domains and the resolution of the model output?
- Has the model been validated to any extent, or undergone intensive scientific peer review?
- Is the model self-contained and, if not, can it be easily coupled to another model, either one already at the CCMC or one that can easily be implemented?
- What types of data are required to run the model, and are additional data sets easily assimilated into the model?
- Can the model be adapted to run on the CCMC computers without major modifications? Is any specific architecture required?
- Is the model robust in terms of its lack of sensitivity to erroneous input?
- Can the model output be easily adapted, either to a space weather product or as an input to another model?
- What computer and networking resources (CPU usage, RAM, disk storage) are required?
- Are any special visualization tools or peripheral display hardware required?
- How much effort will be required from the model developer in the installation, validation, and test phases of the model?
- What types of improvements could be made in the model? What types of testing and validation should be conducted?
- How modular is the computer coding? How well is the code documented?
- Are there any limitations to the use or distribution of the model source code or output?
- Does the model developer consent to model transition from CCMC to the RPCs?

The Steering Committee will periodically review the status of models currently running at the CCMC. Although the goal of the CCMC is to hand models over to the RPCs in a timely manner, many models may remain at the CCMC for further development, for comparison with other models, and for use in on-going scientific studies. It is important to note that there may be several of the same type of model at the CCMC. This is to enable the staff to compare models in terms of accuracy, robustness, efficiency, and compatibility with other models.

3.4 Model Exit Considerations

All major models in the CCMC will be evaluated semi-annually by the CCMC Steering Committee and the two Working Groups to determine its status within the CCMC. The three broad categories for all models are:

- Remain in the CCMC in its current configuration
- Initiate or continue effort to improve the model or interface it with other models
- Remove from the CCMC

The model evaluation will be based on the value of the model to the research and operational communities and the costs associated with the proposed activities. The evaluation could rely on information gained through community-wide surveys administered by the CCMC Steering Committee via the web page.

The value of the model will be based on the following considerations:

- Number of requests for runs from CCMC, researchers and other scientists
- Number of current and planned studies
- Number of recent publications
- Results of validation studies
- Likelihood that improvements will result in significant new capabilities
- Likelihood that model will satisfy science or operational requirements
- Performance of the model against standardized metrics

The cost of a model will be based on the following considerations:

- CCMC staff time required for maintenance
- Impact of model on computer resources
- Staff effort required to implement the proposed improvements
- Staff effort required to analyze model output

In addition to decisions that will be made regarding the status of models within the CCMC, it is also anticipated that mature models will be accepted into the Rapid Prototyping Centers operated by the USAF and the NOAA/SEC. These selections will depend upon the priorities of the operations centers and on the willingness of the modeler. The improved robustness of CCMC models, the results of validation studies, and the documentation written for the use of the model within the CCMC will all be factors that will improve the transition of models from the CCMC to the RPCs and into operations.

In order to assure steady progress of the models from research to operations, the models will be evaluated for their suitability for use at the Rapid Prototyping Centers semi-annually. Models may stay at CCMC as long as they serve a useful purpose there, but models that pass the exit criteria will be made available to the RPCs.

The exit criteria include:

1. **Model Stability.** The model must run for long periods of time in the absence of undue user intervention without crashing, stopping, or exhibiting signs of undue unstable behavior. The details, for example the time period, will be defined in terms of perceived operational needs.
2. **Accuracy.** The model computer programs must satisfy reasonable accuracy criteria. The standard of accuracy here is lower than that for graduation models from the RPC to operations. RPC models must demonstrate that they are accurate enough to satisfy operational needs and will be tested at the RPCs under simulated operational conditions. CCMC models, on the other hand, must show that they are not obviously too inaccurate to be useful for the RPCs or operations. Accuracy will be demonstrated by generating metrics of observed data sets that are considered to be relevant to operations against model output, for example, the RMS deviation between observations and model predictions.
3. **Added value.** The model must show an increased capability beyond models that are currently operational today and a demonstrated need to improve the operational version by documented customer requirements.

4.0 CCMC Operations

4.1 Computational Assets

The system will be implemented in an incremental fashion, with each increment adding or enhancing the system capabilities through upgraded hardware, software, or both. The architecture described below will not necessarily be the only computational architecture CCMC employs. As new technology becomes available, CCMC computational resources will change accordingly.

The initial configuration of the CCMC hardware asset at AFWA was an IBM SP2 with 70 nodes. Recently, these resources have been replaced by a set of parallel processors at GSFC provided by AFWA, NSF and AFOSR. To handle jobs for which these resources are insufficient CCMC will utilize DoD High Performance Computer Modernization Program (HPCMP) facilities. HPCMP resources are described in full at <http://www.hpcmo.hpc.mil>. Among them are IBM SP2s and SP3s located at Maui High Performance Computing Center (MHPCC), an IBM SP at Aeronautical Systems Center (ASC), Wright-Patterson Air Force Base, Ohio, and IBM SPs at the US Army Corps of Engineers Waterways Experiment Station (CEWES), Vicksburg, Mississippi. Accounts will be opened and maintained at the MHPCC and ASC sites.

These machines will serve as overflow resources for CCMC users. Access to the accounts of the machines will be controlled by CCMC staff and will be handled in such a manner that the use of the different machines is transparent to the user. It is planned to

develop an automated algorithm that scans the resources requested for a given job and routes it to the most appropriate computing resource.

4.2 Accessing CCMC Computers

At the present time, there are no plans for outside investigators to have direct access to CCMC computational assets. Special accounts for visiting scientists may be established as necessary. Outside investigators may submit requests for specific model runs. These runs will be executed on a non-interference basis with other CCMC runs.

Most users will interact with CCMC computational assets via the CCMC web page. The researcher will request what model to be run, under what constraints as well as the input data. CCMC scientists will run the model, then provide the output back to the researcher as raw data files or visualized by graphics capabilities available on the web page. Visiting scientists at NASA GSFC may be granted direct access to CCMC computer resources by request. A form exists on the web page to notify the CCMC if this type of access is required.

Compilation and execution of all runs will originate from or be routed through CCMC, the front-end system located at Goddard Space Flight Center, Maryland. The GSFC system will comprise workstations and associated software, local high-performance computers, as well as DoD computational assets connected by the Defense Research and Engineering Network (DREN) or other high-performance networks. Data retrieval from the computational resources will be accomplished by software designed, written, and maintained at GSFC. The retrieval will be done in such a manner that it is transparent to the user.

4.3 Access to CCMC Model Source Code

Source code distribution maximizes benefits of code development to both research and operational communities alike. While source code access by operational entities is critical during the transition process, the CCMC will work with model developers on a case-by-case basis regarding source code distribution to the research community. Any agreements set up between CCMC and model originators as part of the model ingestion procedure will be honored during the entire model residence at the CCMC.

4.4 Determining Standards for Configuration Control and Documentation

Models will be executed as soon as resources permit, initially in the form supplied by the researcher. The CCMC will administer configuration control of source code. Any changes to the source code will be coordinated with the researcher and a copy supplied back to them. In the future, CCMC models will be distributed in an object-based environment and modified for common interfaces. This will facilitate running components of one model with those of others to evaluate performance.

4.5 Network Connectivity

Communication between off-site computational resources and the front-end at NASA GSFC will be facilitated via the DREN, or similar high-performance networks. The research community will submit job requests to NASA GSFC via the CCMC web site or other means. These requests will be submitted by authorized NASA GSFC staff to the appropriate computational platforms, using suitable network connectivity.

4.6 Security

CCMC staff will provide computational security at GSFC as mandated by CCMC security accreditation procedures and GSFC regulations. CCMC staff will also limit access to the CCMC computational assets as mandated by CCMC security requirements.

No classified information will be processed within the CCMC, however, access will be controlled through the CCMC staff at NASA GSFC to ensure computer security as well as source code protection for the system. The AFWA has performed a Certification and Accreditation of the earlier AFWA /GSFC CCMC system. The C&A package conforms to USAF standards for a system of this level. This and other security documentation is available to the NASA GSFC staff, but will not be released to the general public.

Visitors to CCMC desiring direct access to the DoD computational assets or the DREN will require a routine National Agency Check (NAC). If possible, the CCMC Headquarters staff may help interested parties arrange for this.

Computational assets and web services at CCMC will, at a minimum, comply with the present level of NASA Goddard Space Flight Center information technology security requirements. Access, through CCMC, to DoD computational resources will conform to applicable DoD regulations.

Access to the CCMC facility will be controlled through card key access. Approved visitors will be provided with a card key, which will be returned and disabled after the termination of the visit.

Acronym List

AF/XOW	Air Force/Director of Weather
AFOSR	Air Force Office of Scientific Research
AFRL	Air Force Research Laboratory
AFSPC	Air Force Space Command
AFWA	Air Force Weather Agency
CCMC	Community Coordinated Modeling Center
CEDAR	Coupling, Energetics, and Dynamics of Atmospheric Regions (NSF program)
CONOPS	Concept of Operations
COTS	Commercial Off The Shelf
CPU	Central Processing Unit
DoD	Department of Defense
DREN	Defense Research and Engineering Network
GEM	Geospace Environment Modeling (NSF program)
GSFC	Goddard Space Flight Center
ISTP	International Solar-Terrestrial Physics (NASA program)
LWS	Living With a Star (NASA program)
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NSF	National Science Foundation
NSSDC	National Space Science Data Center
NSWP	National Space Weather Program
OFCM	Office of the Federal Coordinator for Meteorology
ONR	Office of Naval Research
OWG	Operations Working Group
RAM	Random Access Memory
RPC	Rapid Prototyping Center (either NOAA or USAF site)
SEC	NOAA Space Environment Center
SHINE	Solar, Heliospheric, and Interplanetary Environment (NSF program)
SMC	Air Force Space and Missile Systems Center
SWG	CCMC Science Working Group