The Original GEM Ideology (1988)

- The idea for GEM (Geospace Environment Modeling) arose from a workshop held at the University of Washington in 1987.
  - Organized by Juan Roederer, Dennis Peacock.
  - The magnetosphere is a very complicated natural plasma system, with different regimes that have to be attacked using different kinds of observations and different theoretical/modeling approaches. Crucial processes occur on vastly different scales.
  - For such complicated natural system, our most advanced understanding is encapsulated in large computer codes.
  - Concept that emerged from the workshop was of a research program that aimed at development of a single computer code that would represent the large-scale physics of the Earth's magnetosphere, including the small-scale processes that affect the large-scale.
    - Theory group led by Maha Ashour-Abdalla. The idea of using that computer code as a focus for the overall program came mostly from Chris Goertz and George Siscoe.
- There would be a series of campaigns aimed at understanding boundary layers, substorms…, each campaign with highly coordinated observational and theory/modeling components.
  - Proposed GEM budget was to ramp up to ~$8 M/yr.
- After all of the 6 campaigns were completed, the final step was to be development of a General Circulation Model for the magnetosphere (analogous to general circulation models for the troposphere)..

GGCM in the Mid-to-Late Nineties

- GGGM Implementation Plan:
  - Need for collaboration of many groups:
  - Envisioned a computational spine
    - Global MHD with embedded supplementary modules to represent non-MHD physics
    - Block-modular structure with different codes reprsenting different spatial regions, with boundaries between them.
  - Envisioned a large national effort to develop a GGCM.
    - Different groups all over the country/world would develop modules representing different regions.
    - Free peer-reviewed independent competitions for the spine and various modules.
  - Some practical problems recognized:
    - Common data interfaces
    - Need for a central facility to coordinate the activity.
    - Code-confidentiality problems.
  - Recognized the need for scientists other than the code's developers to be able to examine results of simulations in detail.
    - To test against observations
    - Try out new ideas.
- Three concept studies were carried out, to develop more specific visions of the GGCM:
  - Dartmouth study based on global MHD spine
  - Rice study based on block-modular structure
  - TRW study emphasized computer-system architecture

GGCM in the Mid-to-Late Nineties

- It was becoming clear that there wasn't going to be a computer program called the GGCM
  - The GGCM had been a dream but also a very useful principle for organizing research.
  - It was clear that the basic goals of the GGCM were going to be realized, though not in a code called "GGCM."
- It was clear that we already had impressive capabilities for simulating Earth's magnetosphere.
- Recognition that the GGCM goal of community availability could be attacked immediately, the GGCM Working Group defined a three-phase program for wider utilization of magnetospheric simulations:
  - Phase 1: Code results easily available to any scientist
    - Best done through a community center
    - Could be implemented immediately via the world-wide web, using existing codes. Jimmy Raeder led by making his results available
  - Phase 2: Any qualified scientist couold commission a model run. (Begins to require a community center)
  - Phase 3: Full GGCM assembled and available
    - Off in the distance.

Big Code-Development Projects with GGCM-Like Characteristics

- Mission Research effort, funded by Defense Special Weapons Agency
  - Basic code covered thermosphere, ionosphere, magnetosphere and interaction with solar wind (MHD spine)
  - Idea of modules was included in the design, to a modest extent (RCM, field-aligned potential drop, substorm, magnetopause reconnection)
  - Accomplishments:
    - Produced a competitive global-MHD code and some interesting science.
    - Team included non-simulation-oriented theorists and observers, demonstrated how non-computational physicists could productively contribute to simulation efforts.
  - Funding decreased sharply after 5 years, before the job was completed.
- Boston University consortium
  - Large team covering solar, heliosphere, magnetosphere, ionosphere, thermosphere
    - Team includes range of experts
  - Separate modules for corona, heliosphere, magnetosphere, ionosphere-thermosphere
    - Block modular with a broader scope.
  - Magnetospheric plan includes modules for radiation belts, ring current…
  - Short-term funding by NSF,now finalist in competition for NSF Science and Technology Center

Big Code-Development Projects with GGCM-Like Characteristics

- Michigan consortium:
  - Large team covering solar, heliosphere, magnetosphere, ionosphere, thermosphere
    - Includes range of experts
  - Plan uses adaptive gridding to use a single overarching MHD code through magnetosphere (MHD spine, applied more broadly than GGCM vision)
    - Magnetospheric modules include inner magnetosphere and radiation belts.
    - Ionosphere-thermosphere is a separate module
  - Funding from NSF KDI program, Air Force MURI, NASA HPCC

Big Code-Development Projects with GGCM-Like Characteristics

- Overall, this is much better than the original GGCM plan in that these "GGCM's" cover the whole space weather problem, not just the magnetosphere.
- It looks like we will get at least two big space weather codes rather than one.
- Departures from the GGCM vision:
  - No free competition for module development.
    - Teams were assembled in the proposal process.
  - Very good people got left out of these consortia

Value of CCMC to GEM: 1. Providing Community Access

- Development of a community code was always the central aim of GEM.
  - Included input from many members of the scientific community
  - Results accessible to the scientific community
- The scientific impact of the GGCM-like mega-models, and the many smaller existing simulation codes that have been developed at various institutions, will be enormously increased if a wide range of scientists can use them
  - For each big code, there is usually a central computational physicist who knows the code best, plus a few others who understand it pretty well.
  - These people are really, really busy.
  - They are only going to do runs to settle questions that they find most interesting. Those might not turn out to be the most interesting, in the long run.
- Wider use of these codes should provide a substantial multiplying effect on the science produced.

Value of CCMC to GEM:
1. Providing Community Access

- The CCMC is providing convenient access to the codes that it hosts. It is a fully developed implementation of GGCM phase-1. It is easy to look at graphical results from the Michigan code, for example.
- It is now possible for an interested scientist to commission a run of the Michigan code, and the CCMC staff will make the run.
- This capability has certainly not yet transformed our field.
  - The capacity has been utilized by a modest number of investigators.
    - Of course, the CCMC staff is also of modest size.
  - People change their ways slowly…
  - As more codes are installed at CCMC and they get better, the utilization of them will increase.
  - CCMC staff will need to grow
- In my GEM-based perspective, this is fundamentally the most important scientific service that CCMC can provide for the GEM community.

Summary Comments on CCMC and GEM

- From my GEM-biased viewpoint, the idea for CCMC arose out of GEM's long-time goal of a community computer model of Earth's magnetosphere.
- The CCMC is half of the realization of GEM's longstanding dream of a GGCM.
  - CCMC offers the promise of converting individual team simulation capabilities into community capabilities.
    - I think this will eventually increase the overall usefulness of these codes by a substantial factor.
- CCMC is a mechanism for validating codes and uncovering their limitations.
  - This is an essential function if GEM research is to have practical benefit.
- CCMC seems the best institution to oversee metrics
  - We have to have quantitative measures of our progress if we are to justify part of our funding as being for practical benefit to society.