GRASS Roots

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1 Introduction

GRASS, the Geographic Resource Analysis Support Software, is nearing 25 years of age and has recently attracted a whole new generation of users and developers. For this community, many of whom are younger than GRASS, a glimpse into the early years of GRASS design and development will be surprisingly familiar. The environment within which GRASS was developed and the needs of its community then, mirror the current environment and needs. A short history of GRASS in the form of short stories below will take us from the conception of the baby GRASS through its childhood, its teen years, and into adulthood. We then conclude with a comparison of user needs that shaped GRASS at its beginning with those that shape its future.

2 In the Beginning

The year is 1978 and the place is the Champaign/Urbana, Illinois in the United States – home of the University of Illinois (35,000 students) and the Army Corps of Engineer's Construction Engineering Research Laboratory (CERL) (about 200 people). A small group of researchers including Ron Webster, Harold Balbach, Robert Lozar, and William Goran are dabbling with GIS. The GIS in use was RIA, the Resource Inventory Analysis system running on an IBM-360 mainframe computer. A 2.5 Gbyte disk for the machine cost about $87,000 and user time was tracked and billed.

Harvard University had graduated Jack Dangermond with a M.S. in landscape architecture in 1969 and he was now offering geospatial services to clients through his business called the Environmental Systems Research Institute (ESRI). Harvard had developed a series of GIS capabilities including SYMAP and ODYSSEY and the commercial ARCINFO built on the experiences with these systems.

Between 1978 and 1980 I developed a small GIS package called LAGRID – the Landscape Architecture Gridcell analysis system for a M.S. thesis project with Dr. Lewis Hopkins as my principal academic advisor. We, at CERL, decided to purchase ARCINFO and entertained Jack Dangermond twice at our laboratory. ARCINFO was clearly the most capable and useful GIS software at the time and Mr. Dangermond was a person that we really wanted as a part of our GIS efforts. Unfortunately we were not able to fund the $15,000 cost of the software and the $60,000 cost of the minicomputer required to run it. We decided to develop some marketing tools by demonstrating GIS capabilities using an inexpensive Cromemco Z80 micro-computer. It had about 32KB of memory, ran at 8 Mhz, had 8-inch floppy disks, and a 377x241 pixel 16 color monitor. I ported the FORTRAN-based LAGRID software to this machine and created some sales material, which generated a little bit of funding from the environmental office at Fort Hood, Texas. Unfortunately, this was not enough to enter into the hoped-for long-term relationship with ESRI. So, we created the Fort Hood Information System (FHIS) using the wonderful programming skills of L. Van Warren. At this time we tapped into available computers and software – the PDP-11 and the Unix operating system. Unix was developed at Bell Laboratories for their own use, but the government did not allow this telephone company to market their creation. Instead UNIX was shared with all interested parties and a growing movement within computer science departments at universities was

resulting in lots of software being contributed into the Unix freeware community. FHIS was UNIX-based and made use of new 300-baud (300 bits per second, 40 bytes per second, .04Kbytes per second) modems to connect the Fort Hood users on a vector-based CRT with the software running at the University of Illinois 600 miles (900 km) away. A dot-matrix printer was used to generate black and white maps. Printers at this time did not have associated drivers, but rather manuals describing the printer's language that software needed to generate. FHIS was successful enough to attract interest from the Fort McClellan, Alabama environmental office, but still not enough funds were available for Jack's ESRI software.

3   The Conception

The 300-baud modem experience proved unworkable and we determined that a computer must be placed at the user's site. It is now 1983 and the first small UNIX computer was being offered by the just created Sun computer company. Michael O'Shea joined our little group as a programmer and we purchased a Sun-1 computer for our development purposes and one for Fort McClellan and delivered a system called IGIS – the Installation GIS. This system moved data from inside the programs (as in FHIS) to data bases, making it possible to use the same software for multiple locations. IGIS sported a SUN color monitor, which was separate from the monochrome monitor used to enter commands. Our Fort McClellan customer, Ray Clark, chief of the environmental office was impressed with the new computer and software for his office and, upon seeing the first map image on the screen asked "Can you rotate it?" We were amazed that he wasn't aware of what was required to just get the image on the screen- and in color. The Star Trek television series had really raised expectations within our target user community.

4   The Birth

With the success of IGIS we now had interest coming in from several potential customers and we continued adding more capabilities. Another new company offering UNIX within a small computer called MASSCOMP provided us with the need to port our software. Also, new color dot-matrix printers allowed us to create our first color hard-copy maps. With a swelling of new customers, the need to maintain the software on multiple computers running at multiple sites, we packaged our 20 programs and called the turn-key solution GRASS – the Geographic Resource Analysis Support System. The name continued a series of GIS names based on plants: SAGE, a DOS-based GIS, and MOSS (Mapping Overlay Statistical System), developed by The Bureau of Land Management (BLM). Our suite of GIS demonstration programs, intended to attract enough interest from our user community to allow us to become one of the first ESRI customers, was now packaged and named as a real GIS system. This baby grew rapidly and we abandoned our hope (and need) to purchase ESRI software.

GRASS was distinguished from ESRI software in a number of important ways. ESRI had chosen, at that time, to not support UNIX, but to rather work with commercial operating system vendors. ESRI software was vector-based and had virtually no raster-processing. There were vector-raster wars in the GIS community – each extreme claiming that everything that needed to be done could be done with their approach. Vector processing was perfect for human environments and could efficiently and accurately hold coordinates that identified edges of human built and defined things. Raster processing was more suitable for environmental, or natural systems, where edges often are not found. ESRI software was commercially developed and supported and perfectly suitable for the largest segment of the community. GRASS software was developed completely out of our laboratory, but we understood that we would never see enough funding within our target user community to allow us to fully develop GRASS. We diverted a significant part of our effort to making it possible for anyone to write needed GRASS software and embraced the open-software philosophy already adopted by the UNIX community.

GRASS user sites grew to 13 sites including Fort Lewis, Washington, Central Washington University, and The Army National Guard headquarters.

5 Childhood

Childhood is an exciting time; a time when everything changes rapidly; a time of dramatic growth. The GRASS community had grown to a point where it became obvious that this community needed an opportunity to meet and share experiences. The first annual GRASS user meeting was hosted by Emmet Grey and the environmental office at Fort Hood, Texas. Perhaps 30 people enjoyed presentations and software sharing at this event. Each year the annual event was hosted by a different part of the user community, grew in attendance, and lasted longer. With this first conference GRASS 1.0 was released – indicating a naming convention that recognized that a future for GRASS design and development was assured. Major numbers (e.g. 1.0, 2.0, etc) would reflect major changes. Decimal numbers (e.g. 1.1, 1.2) indicated upgrades and bug fixes that could generate output readable by earlier versions. In some cases letters (e.g. 1.1a, 1.1b) would be used to indicate notable "builds" that often contained critical bug fixes.

Many software users, supervisors, and managers viewed software as a physical product that could be "completed". With each release there were expectations that GRASS development was done. As lead developer I needed to carefully choose the time and place to reveal that a next release needed to be planned to fix known bugs and to provide users with new code. Yes, we did release code with known bugs and we did release code before the software was "done". It took years to convince some that when new releases are not planned, software is more likely "dead" than "done".

With GRASS 1.0, a major newcomer to GRASS was the National Parks Service. GRASS sites now numbered about 20 and the number of new users prompted Dr. Jim Hinthorn at Central Washington University to begin offering GRASS classes.

The 1986 release of GRASS 1.1 responded to the originally unimagined need for raster files larger than 100 by 100 rows and columns by using run-length encoding for raster maps, and to a new need to hold values larger than 255 in cells by using multi-byte values. Image processing was introduced through the programming of Michael Shapiro as a GRASS sub-system. On the management side, Bill Goran created the first GRASS Interagency Steering Committee (GISC), and members included:
>   Emmet Gray – Fort Hood
>   Bruce Powell – National Park Service
>   Gregg Petrie – Washington
>   Jim Hinthorn – Geology Department CWU
>   Marc Levine – Army National Guard
>   Paul Coho – Yosemite National Park
>   Jean O'Brien – CERL
>   Margaret Maizel – American Farmland Trust
>   Jim Farley – Arkansas Archeological Survey
>   Dave Becker Fort Lauderdale Office of Planning
>   Gary Ahlstrand – Alaska Regional Office, NPS
>   Ralph Root – National Park Service GIS
>   Gary McCausland – Forestry, Fort Lewis
>   Denis White – Harvard University

In 1986, GRASS received the Exemplary Systems in Government Award from URISA. The growing user community began to be served by a newsletter – GRASSCLIPPINGS, which Linda Loy skillfully edited and produced over the next six or more years.

By now, the dreams of the GRASS development staff far outreached the prospective funding and the first GRASS programmer documentation was developed. This was provided to contractors developing code and allowed independent developers to create

new code without support from the original developers. (Hardcore programmers always believed that the open source was the only documentation necessary.) In 1987, GRASS2.0 was released and offered more programs and improvements. It was ported to about 7 different computer systems, with some of the ports and support offered by different commercial interests. Distribution of GRASS covered about 100 sites and the Soil Conservation Service provided a formal beta test.

In the following year, 1988, we released GRASS 3.0, which offered significant fundamental improvements. While remaining primarily a raster-based system, the image processing sub-system was fully integrated into GRASS as a central feature. The vector sub-system of GRASS was primarily a digitizing package designed to create raster maps from original paper maps, but was completely recreated and now also offered vector analysis and processing. Raster file formats were changed to support 1-4 bytes per cell to accommodate very large integer numbers and were portable across different computer systems (parsing of the bytes was accomplished in a specific way by GRASS software libraries).

By 1989 a group of over 20 people at CERL was busy developing, supporting, and running GRASS. Application specialists such as Mark Johnson, Jean O'Brien, Kelly Dilks, and Marilyn Ruiz helped military installation planners with environmental, archaeological, and regional analyses. Repeat customers kept a solid line of funding to develop data and conduct studies.

6   Teen Age

In 1990 GRASS 4.0 was released and GRASS had entered its rebellious teenage years. The child was invincible, had its own plans, and was looked forward to moving out of the house. But, as good parents, we were not ready to let it out on its own. GRASS 4.0 was released in the form familiar to current users. The letter-dot format (e.g. d.rast and g.region) was adopted to help ensure low-probability of conflict with other UNIX commands, but to retain the notion of different sets of commands. While the early decision to first develop GRASS as a command-line system remained good, the need to provide users with a GUI was increasingly difficult to ignore. A first step was taken to help bring interface consistency across the GRASS commands. A standard way to process command-line arguments was developed and added to every program. This also provided automatic user prompting and help options to users of nearly all commands. Also, we accommodated an automatic way to identify the appropriate program (command line or GUI-based) to run. GRASS 4.0 was released with a user reference manual and a number of universities developed courses and course materials to match the growing user demand. The user community was about 40% Federal, 5% state and local, 25% private, 25% educational, and 5% foreign.

In 1990 a GRASS Directory was published listing over 60 companies that offered services that included turnkey systems, training, support, data development, applications, and software development. GRASS was mainly distributed on tape, which helped control and track its distribution. A key development for GRASS at CERL was the joint creation of a new GIS laboratory with the Departments of Geography, Landscape Architecture, Urban and Regional Planning, and Anthropology at the University of Illinois. Professor Douglas Johnston was the primary director of the lab and help guide many GRASS efforts over the next decade.

Software efforts were underway to develop an X-windows user interface and to add floating-point support to GRASS. Joo Joo Chia worked on an early interface to the GRASS commands Kurt Buehler completed the development of XGEN, started at MIT, which allowed for the rapid development of GRASS-based decision support systems. Irina Johnson and Michael Shapiro modified the GRASS libraries to support floating-point data I/O and processing and then reworked every program accordingly – a monumental effort.

But, the teenage GRASS had other plans. Complaints from the commercial GIS industry claimed that it was unfair for the Federal Government to be competing with them. Government offices were more frequently able to purchase ESRI or IDRISI software as their

prices and the price of CPU power dropped. Although GRASS design and development continued, GRASS releases became less frequent which helped accelerate the movement of the GRASS user community towards commercial software.

What was GRASS to become as an adult? In 1989 the GISC considered awarding three Cooperative Research and Development Awards (CRDA) to fully tech transfer the design, development, maintenance, and support of GRASS into the commercial marketplace. The GISC carefully defined their goals for the CRDA and determined that the goals were being met without the CRDAs. The desire to maintain GRASS in the public domain conflicted with industry interests in transferring "ownership" to one or more companies. We ended up entering a phase of continued development, but no formal releases of GRASS.

Finally, in 1992 CERL signed a formal Cooperative Research and Development Agreement with the Open GRASS Foundation (OGF), which replaced the GRASS Interagency Steering Committee as the GRASS coordinating force. David Schell was Chairman and Executive Director and long-term GRASS steering committee forces played important roles (Secretary – Kenn Gardels; Treasurer – Fred Limp). OGF coordinated the final two user conferences, but found funding too challenging. It switched its focus and name, becoming the Open GIS Foundation and has now served for over a decade as a formal connection among commercial GIS developers.

A 1993 GRASS presentation described GRASS as follows:
- Software
    - 200 user programs
    - 4000 software files
    - 300,000 lines of code
    - 300 library routines
    - 15 locations developing code
    - 5- person-years of development time
    - GRASS-Garden
      MAPGEN (USGS), plotter ouput
      LTPLUS (Forest Service) – scanner input
      GCTP (USGS) – coordinate transformation
      XGEN (CERL) – X-window interface
      RIM (Univ of Washington) – relational DBMS
      PBMPLUS – image file transformation
      HDF (NCSA –U of Ill)

- Major Awards
  1986 – Urban and Regional Information System Association (URISA) – Exemplar Systems in Government Award
  1988 – Secretary of the Amy for R&D – R&D Award
  1993 – Federal Laboratory Consortium – Technology Transfer Award
- Institutions Using GRASS
  Canadian Army
  Quebec Hydro
  Spanish Army
  Australian Army
  IL Department of Environmental Protection
  NY Port Authority
  Kenya National Park Service
  U.S. National Park Service
  U.S. Army
  U.S. Air Force
  U.S. Navy

U.S. Soil Conservation Service
CA Department of Water Resources
U.S. Agriculture Research Service
U.S. National Weather Service
U.S. Fish and Wildlife Service
U.S. Forest Service
AR Fish and Game
Federal Bureau of Investigation
Bureau of Land Management
Bureau of Census
Bureau of Indian Affairs
Environmental Protection Agency
NASA
NOAA

- 13 Organizations provided GRASS training
- GRASS Organizations
  GRASS Inter-Agency Coordinating Committee
  Open GRASS Foundation
  European GRASS Foundation
- Past Conferences
  1985 Fort Hood, Texas
  1986 Fort Lewis, Washington
  1987 NASA Institute for Technology Development, Stennis Space Center
  1988 CERL, Illinois
  1989 U.S. Soil Conservation Service, Virginia
  1991 Univ of California, Berkley
  1992 National Park Service, Colorado
  1993 US Geological Service, FBI, and SCS, Virginia
  1994 Hosted by SCS Reston, Va, Sponsored by The Open GIS Foundation

7   Young Adult

With no more GRASS releases scheduled by its "parents", GRASS was officially a young adult – moved out of the house into the world of possibilities. Its OGF home did not last long and a backlog of improvements, bug fixes, conversion to floating point, and new GUI were not getting out to its community in any coordinated fashion. A number of key individuals were responsible for keeping GRASS alive at this time. Helena Mitasova and Bill Brown, located at the GIS Laboratory at the University of Illinois continued to support development of new GRASS software – especially hydrologic analysis and 3-D visualization. Irina Johson completed conversion of GRASS programs to support floating-point numbers and the null value. The user community did not benefit and resorted to acquiring commercial GIS software. Many universities continued to use GRASS for conducting R&D that extended the capabilities of GIS. One example was William Baker's r.le set of programs out of the University of Wyoming.

Most commercial ventures relied on the continuous development of GRASS by the government, but one notable exception was the 1989 effort by Gilles Clement, president of L.A.S., a new Toronto, Canada company. L.A.S. created GRASSLAND, which provided a powerful GUI environment for building GRASS-based projects and analyses. GRASS programs were connected graphically by flows of maps creating projects that could be saved. This product was eventually set aside for a more lucrative product that served, over the Internet, maps from many different vendors and in many different projections and coordinate systems. GRASSLAND is probably the best interface to GRASS ever developed. L.A.S. also created a Windows-95 version of GRASS.

One day Bruce Byers from Baylor University in Texas called by phone and exuberantly described a plan for his university to become the new home for GRASS. We were able to gather together all of the good software developments that had not yet been released and his group pushed to get out the next release. Bruce met Markus Netler who shared the dream of a future for GRASS. Their collaboration laid the foundation for today's GRASS releases.

8 Summary - Now and Then

While details of the the names, faces, and stories associated with the early years may not be known, the needs and desires of those people is reflected in the software. Those attracted to it today and in the future share a kindred spirit or relationship to each other – across time, space, and culture. The reasons leading to GRASS success in the early years still exist today.

- A powerful public-domain GIS was needed to support environmental planning.
- The primary user community was not wealthy and could not afford the price tag of available commercial systems.
- Novel GIS analysis approaches were needed and only an open system provided the opportunity for efficient development of new software.
- The core system (libraries or APIs) were maintained by a core group, but anyone interested could improve existing programs or develop new programs.
- Annual user meetings were held to help sustain and grow a self-supporting community.
- A newsletter provided an opportunity for users to learn about new opportunities, experiences of others and support.

These reasons will continue to persist and ensures a long life for this once small child and difficult teenager. GRASS has grown into a fine citizen of the world and offers powerful environmental planning capabilities that will continue to help us care for our earth.

The author understands that many hundreds of people have played significant roles in the development of GRASS over its life and that only a few were mentioned in this short history.

9 Early CERL GRASS Publications

A DSS for Corps Regulatory Functions ,Paul Loechl (1994).
> COE districts regulate activities conducted on and near waterways through the issuance, modification, and denial of permits, based on an assessment of activities' environmental impacts. Such regulation requires that districts and district field offices evaluate the probable and cumulative impacts of proposed activities on natural, cultural, and economic resources. A prototype graphical user interface has been developed to link a relational database management system (RAMS) containing data relevant to the Corps regulatory process with spatial data analysis and manipulation functions (GRASS GIS), using linking software (RGI) and the integrating framework of a customized X-Windows based user interface (using XGEN). This prototype has been since recast into a prototype decision support system (DSS) framework, to provide the integrated spatial database management and DSS functions needed by Corps regulators to rapidly evaluate the impacts of actions subject to Corps regulatory jurisdiction.

Applications of Global GRASS, in the Proceedings of the March 1991 GRASS User Group Meeting, CEDR-02-92 ,Lozar, Robert C. (1992).

Design Issues: Integrating Imagery and Other Geographic Data Sources within GRASS ,Goran, William D. , Lozar, Robert C. and Michael Shapiro (1987).

Finite element modeling of storm water runoff using GRASS GIS ,Vieux, B.E., and J. Westervelt , Report Number (1992).

> Presents methodologies that are under development combining the finite element method and GRASS GIS. Grass 4.0 is a raster based GIS written by USACERL. GRASS-FEA is an internationally integrated simulation model and GIS software under development that simulates storm runoff and sedimentation. Land managers will be able to use this system to analyze land use changes, and vegetative cover disturbance using inputs from the GRASS database for slope, soils, and vegetative cover.

Geographic Resources Analysis Support System (GRASS) version 4.0 user's reference manual ,Westervelt, James D., Shapiro, Michael; Goran, William D.; Gerdes, David P. , Report Number N-87/22 (1987).

GRASS 3.0 programmer's Manual ,Shapiro, Michael; Westervelt, James D.; Gerdes, Dave; Higgins, Michael E.; Larson, Marjorie S. , Report Number N-89/14 (1989).

GRASS as an integrated GIS and visualization system for spatio-temporal modeling ,Brown, W.M., M. Astley, T. Baker, and H. Mitasova (1995).

> Increasingly, geoscientific data is being measured in three dimensional (3D) space and time for studies of spatial and temporal relationships in landscapes. To support the analysis and communication of these date, a new approach to cartographic modeling is emerging from the integration of computer cartography and scientific visualization. This approach, in this paper called multidimensional dynamic cartography (MDC), is based on viewing data processed and stored in a Geographical Information System (GIS) in 3D space and visualizing dynamic models of geospatial processes using animation and data exploration techniques. Such techniques help researchers refine and tune the model in addition to making the model easier for others to understand. We describe various aspects of MDC implementation within GRASS GIS and illustrate its functionality using example applications in environmental modeling.

GRASS GIS in the Military ,Lozar, Robert C. (1990).

GRASS in Service to the Federal Government ,Lozar, Robert C. (1989).

GRASS to ARC/INFO Data Conversion ,Dilks, Kelly, Edward Delisio, Mark Gibb, Chris Rewerts, Eric Bader, Gail Taylor , Report Number 98/66 (1998).

> This guide is targeted toward individuals that use geographic information system (GIS) technology. It describes several techniques for translating data from Geographic Resources Analysis Support System (GRASS) format data files to the ARC/INFO data format used with Environmental Systems Research Institute, Inc. (ESRI) products. The primary conversion routines discussed here are a result of a collaborative effort between the U.S. Army Construction Engineering Research Laboratory (CERL) and ESRI. GRASS is a public domain geographic information system originally developed by CERL. This report is intended to be used as a reference during the data conversion process; it describes the two data formats and contains tips that may facilitate the conversion process. link

GRASS Tutorial: r.weight ,Tweddale, Scott A., Westervelt, James D. (1991).

GRASS User's Guide, Version 4.0 ,Goran, W.D., W. Fredrick Limp, Michael Shapiro and James Westervelt (1991).

GRASS/GIS Implementation Guide ,Westervelt, James D., Martin, Mary V., Goran, William D., Lozar, Robert C., Messersmith, Jean M., Ruiz, Marilyn S. , Report Number N-90/02 (1990).

Installation-Wide GIS Implementation Issues ,Diane L. Szafoni, Jason J. Casanova, Douglas M. Johnston, and Kelly M. Dilks , Report Number TR-00-16 (2000).

> In spite of the large investments in geographic information systems (GIS) technology and software by the Army and other institutions, implementation has typically occurred in more of an ad hoc manner than preferred, and more decentralized or "grass-roots" initiated than from a comprehensive information resource management perspective. Some of the problems inherent with this history include insufficiently documented data, redundant and divergently evolving data, incompatible system and file formats, and a disconnect between the capabilities and expectations of a growing user community, and the individuals and organizations historically managing these resources. Enterprise GIS borrows from Enterprise information models used in the broader information systems industry to create a comprehensive framework for providing user information and minimizing problems due to the distributed and disaggregated implementation. This report discusses Enterprise GIS and a comprehensive review of the organization and implementation of systems at an installation to guide future information resource allocations. An installation-wide data model should be developed to identify a common set of data for installation-wide use, collection and attribute standards, accuracy requirements, and maintenance plans (periodicity of updates, notification procedures, etc). User-appropriate interfaces should be developed to minimize unnecessary training or diversion from missional requirements. link

Integrating Land Management and Training Through ITAM and GRASS ,Goran, W.D., and W.D. Severinghaus (1991).

Modeling spatially and temporally distributed phenomena: New methods and tools for GRASS GIS ,Mitasova, H., M. Lubos, W.M. Brown, D.P. Gerdes, I. Kosinovsky, and T. Baker (1995).

> The concept of GRASS (Geographic Resources Analysis Support System) as an open system has created a favorable environment for integration of process-based modeling in GIS. To support this integration a new generation of tools is being developed in the following areas: (a) interpolation from multidimensional scattered point data, (b) analysis of surfaces and hypersurfaces, (c) modeling of spatial processes and, (d) 3D dynamic visualization. Examples of two applications are given-spatial and temporal modeling of erosion and deposition and multi-variate interpolation and visualization of nitrogen concentration in the Chesapeake Bay.

Performing Boolean Operations in GRASS4.0: r.combine Program Tutorial ,Tweddale, Scott A., Westervelt, James D. (1991).

Performing Map Calculations on GRASS Data: r.mapcalc Program Tutorial ,Tweddale, Scott A, Larson, M., and Shapiro, M., (1991).

Predicting Database Requirements for Geographic Information Systems in the Year 2000: Long-Term Design Issues for GRASS ,Buehler, K.A., M. Shapiro, and J.D. Westervelt , Report Number EC-92/01 (1992).

> Explores ways in which the GRASS geographic information system might be improved in capability. Of the many possibilities, the highest-rated options were to link the spatial database to a relational dbms or to an object-oriented dbms. This would enhance management of voluminous non-spatial elements while retaining association with the spatial context.

Proceedings of the 1988 GRASS User Group Meeting ,Lozar, R., ed. , Report Number N-89/18 (1989).

> Presents papers from the 1988 Annual Grass User Group Meeting. Grass is a land management support tool originally developed to help military installations ensure realism in training while conserving the environment. The papers are group as follows: applications, data concerns, and integration of GRASS with other packages.

Put GRASS on Your Lap: the Public Domain GIS on a 386 Notebook ,Lozar, Robert C. (1994).

Sites of the World:` A New Global GRASS CDROM ,Lozar, Robert C., Madry, Scott, and Xu, Jianping (1994).

Sources of Digital Spatial Data for Geographic Information Systems ,Johnson, M.O., and W.D. Goran , Report Number N-88/01 (1987).

> Identifies digital data sources to help installations evaluated the feasibility of implementing systems such as GRASS (Geographic Resources Analysis Support System), which requires digital spatial data. Included is a list of the following characteristics for each source: format, scale/resolution, coverage, media, costs, and a textual description.