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UNLOCKING THE TREASURE CHEST OF LEVEL-II RADAR DATA: LESSONS IN TECHNOLOGY TRANSFER POLICY FOR THE ATMOSPHERIC SCIENCES

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1. INTRODUCTION

1.1. PREFACE

This analysis of Level-II radar data presents a great success story about partnerships in technology transfer, but it didn't have to be this way. Everyone I spoke with about Level II radar – and I mean everyone, from technical folks to the users of Level-II data – all wanted to make the point that **getting this data out in real time is a grand success story of collaboration between government, academic and private sector individuals and organizations**. Nobody denies that the nation is now better off because of the real-time dissemination and archival capabilities that were not available before the operational start of the Level-II program in April 2004. **For all intents and purposes, this policy analysis of the Level-II radar program recounts a productive and professional decision-making system.**

However, I don't want to mislead my audience into thinking that success stories like this are routine in the atmospheric sciences or can easily happen again within the present framework of the weather enterprise. The story of Level-II radar data could serve as a future model for meteorological information transfer between the sectors, but there are two overarching problems that could prevent future success stories.

First, the current weather enterprise in the United States does not use a systematic process to evaluate the successes and failures of current meteorological measurement and dissemination systems, nor does it keep records to understand the users of these systems. In the year since the National Weather Service (NWS) began to disseminate the Level-II data, no organization(s) (NWS, academic, or private) made a systematic attempt to evaluate the effectiveness of the program or to gather metrics on its successes and failures. Organizations do this in a piecemeal and anecdotal way, but there was no systematic evaluation. Lack of this systematic, on-going programmatic evaluation delays continuous improvements since program participants (both providers and users of the data) are not given an appropriate opportunity to provide meaningful and measurable feedback.

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Second, the current weather enterprise does not incorporate a systematic process to evaluate and prioritize future technology development and collaboration opportunities. There were a very few dedicated individuals that initiated the development of a real-time dissemination system for Level-II data (project CRAFT) and who did not let the hope for real-time Level-II data die. What if these people didn't all come together at the same time? What if there were personality conflicts between these people that prevented collaboration? What if they didn't believe so strongly in the eventual success of CRAFT and the Level-II program? The answer is that we would have no Level-II program or that it would have been delayed; both of these answers are unacceptable. Because there is no systematic process to evaluate and project future technology development and cooperation, there is no "back-up" in place for the community if we didn't "happen to have" the few folks who started CRAFT. That is, no organization, committee, or decision-making body would be in place to analyze the current weather enterprise and say, "A major priority is to disseminate and archive the Level-II data in real time."

Again, I want to stress the point that the Level-II program was a success in both the 35,000ft view of U.S. weather information policy and also down at the ground level view of professional and organizational collaboration. But I do not want the aforementioned enterprise-wide lessons to go unnoticed, so I put them here – right up front.

1.2. THE GOAL OF THIS REPORT

This paper uses the case study of Level-II data to develop overall lessons learned for the atmospheric sciences in technology transfer policy and data sharing policy. The National Weather Service (NWS) installed 121 WSR-88D NEXRAD radars across the country during their modernization in the late 1980s and early 1990s (Friday Jr. 1994). Because the cost of this radar network was nearly $1 billion, "The...[weather] community should be in a position to capitalize on this major and valuable national resource..." (NRC 1999). Part of this major and valuable national resource is the high resolution Level-II data from the NEXRAD network. Although this is the highest quality data produced by the radars, it was not until the late 1990s and early 2000s that individuals and organizations collaborated on a scheme for real-time dissemination and archival.

Because collaboration among the academic, government, and private sectors will result in the greatest positive return from society's investment in weather-related infrastructure (Dutton 2002), *this report seeks to develop a set of lessons learned and best practices in data and technology policy in order for the weather community to realize the maximum value of the nation's investment in weather infrastructure.*

1.3. WHY STUDY LEVEL-II RADAR DATA?

This study of Level-II data presents an opportunity to learn from what is generally considered a successful technology transfer program. A conference sponsored by the U.S. Weather Research Program (USWRP) in 2000 noted that the weather community often works at cross-purposes and each sector "...has viewed the other with suspicion, confident that they could ignore the needs and desires of the other members of the community and focus on their own interests" (Pielke Jr.; et al. 2003). The suspicion and tunnel vision often present in the weather community was notably absent in the process to take Level-II data from an inefficient and incomplete tape archival system to a real-time dissemination and archival system supporting mission-critical needs of the private sector and modeling communities.

Perhaps the reason for the lack of contention and collaborative nature of this undertaking stems from the value of the Level-II data. The academic and research community proved that assimilating real-time Level-II data into near-term convective models greatly improves model performance (Droegemeier; et al. 1999). Further, the continued growth of the private sector indicates the increasing number of users who understand the value of meteorological data and expertise (Pielke Jr.; et al. 2003).

Data is the currency of the information age, and as technology advances allow providers and users of data to transfer more and more information, the effect will only be a positive one for commerce. Peter Weiss' "Borders in Cyberspace" (Weiss 2004) study presents an economic analysis of data, and finds that as publicly funded data is shared more freely and equitably, the value for society increases dramatically. The U.S policy of free or cost recovery distribution of data contrasts with the European policy of limited access and high cost. This creates a much larger private sector here in the U.S., both in terms of total workforce and in the exchange of money (Table 1).

Commercial Meteorology in the U.S. and Europe (U.S. $)		
	U.S	**Europe**
Gross Receipts	$400-700 million	$30-50 million
Number of Firms	400	30
Number of Employees	4,000	300

Table 1: Commercial meteorology is much larger in the U.S. compared to Europe, where policies governing the dissemination and cost of weather data are much more strict (Weiss 2004).

Weiss also shows in Figure 1 how this European model directs the money spent on data back to the agency which produced the data, compared to the U.S. system of allowing open and cheap access to data that ultimately promotes economic development outside of government, which translates into both greater wealth for society as well as increased receipts for the government from increased taxes.

Clearly, Weiss shows the monetary value of the U.S. data policy. The monetary benefits behind the development of the Level-II data dissemination system – increased grants for research institutions, new products for the private sector, greater value and wealth for society – are an important reason to study the development of the Level-II system.

Although it is sometimes difficult to assess the direct monetary value of data for society as a whole, other assessment measures point to the similar high value of weather data. After the NWS modernization installed 121 Doppler radars, tornado warnings markedly improved. The percentage of tornadoes warned increased from 35% before WSR-88D installation to 60% after installation while the mean lead time on warnings increased from 5.3 minutes to 9.5 minutes as the false alarm ratio fell slightly (Simmons; Sutter 2005). These statistics do not speak to the value of Level-II data directly, but they do show the human-interest value in radar data as a whole. And to continue improvement in forecasting and saving lives, the aforementioned assimilation of real-time Level-II data led to more precise model forecasts of the

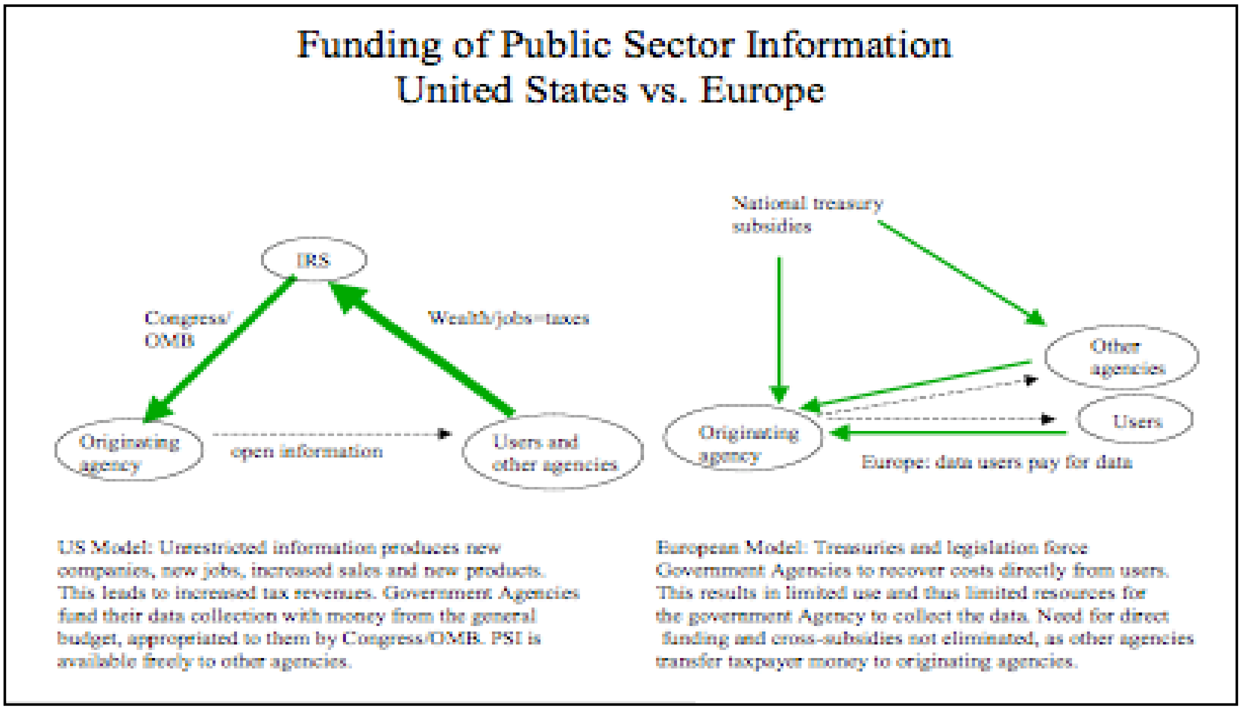


Figure 1: The flow of money from open and low-cost dissemination of data in the U.S. contributes to greater overall value to society. The European high-cost / reimbursement model directs most money back to the government agency that produced the data.

May 3, 1999 tornado outbreak in Oklahoma compared to the model forecasts that did not incorporate the real-time Level-II data. Citing project CRAFT which was operating on a regional level during the 1999 outbreak, Professor Kelvin Droegemeier commented that without this project the more accurate forecasts for the tornado outbreak and the post-event analysis using archived Level-II data would have been impossible (Henson 2004).

Although a policy analysis of a successful program is important, the value of such an analysis is limited if there is no room to suggest alternative actions to improve upon the current policy. In this vein, there is still a great deal of room for improvement in the dissemination of Level-II data. Beyond the generally shared interests of those involved in the Level-II system, structural weaknesses in the weather community are omni present and threaten to keep the use of weather information from achieving its full potential. Some argue that among rather mature sciences, weather and climate are the last frontier in technology policy (Pielke Jr. 2005 (submitted)). Specifically:

> The problem...is that participants in the national enterprise for the provision of weather and climate services lack the means to judge appropriate roles and responsibilities from the standpoint of meeting national goals, and they suffer from a lack of mechanisms (e.g., institutions, leadership) to reach shared expectations on roles and responsibilities. Part of the reason for the lack of means and mechanisms is that the weather and climate services enterprise
> is highly complex and sprawls across government, private and academic sectors. Further, national goals related to the provision of weather and climate services are many, and in the promulgation of goals into specific policies, many conflicts among policy objectives have been introduced. Conflict is exacerbated by national science and technology policies that force integration of the public and private sectors (e.g., the Bayh-Dole Act). Identification of conflicts – much less their resolution – is hampered by the lack of a "forest" scale perspective on weather and climate services. Instead, there are many with a view of individual "trees." The lack of such a perspective means that debate and discussion over the decades has largely been engaged by those with a

> clear stake in particular outcomes. Consequently, the provision of weather and climate services has been treated much less like a policy issue to be assessed and addressed, than a political issue to be won (Pielke Jr.; Carbone 2002).

In a more concise view, Pielke Jr. (2005 submitted) states, "To the extent a lack of shared expectations has limited the transfer of scientific and technical knowledge into products and services, national interests are not served." So although those involved with the Level-II dissemination program generally agree that this is a GREAT step forward for the weather community, this analysis must look more closely at the Level-II program to understand if national interests are truly being served in the most efficient manner possible.

In fact, there is still room for considerable improvement in the provision of Level-II data. The NOAA budget summary for FY 2006 (October 1, 2005 to September 31, 2006) states that the agency delivered satellite products to support the forecasts of hurricanes Charlie and Frances in 2004 with a 100% and 99.9% delivery rate, respectively (NOAA 2005). In the provisioning of Level-II radar data – which is similarly critical as satellite data – the current (FY03-FY06) NWS requirements are 'only' 95% (Crum; et al. 2003). In reality the reliability of the data feed is usually over 99%, but this discrepancy in requirements is a sign that room for improvement does exist both technically and from a strategic goal-setting perspective.

The Commercial Weather Services Association (CWSA) stated in an in April 29, 2005 press release:

> Through more than 55 years of innovation by the Commercial Weather Industry and a policy of free and open exchange of government information, the American public has become the beneficiary of the best weather information available anywhere in the world...Unfortunately, the performance of the National Weather Service in fulfilling its key tasks of collecting and disseminating government information has not always kept pace with public and private needs..."
> (Commercial Weather Services Association 2005)

The CWSA praises the NWS for its policy to disseminate the data at low cost to anyone who wants it, but the CWSA also questions if NWS is prioritizing its resources in such a way to maximize the value of weather information to the country by ensuring accuracy and reliability in its data systems. And this leads back to the reason for completing this study of the Level-II data program. The scientific accomplishments and organizational collaborations to produce the Level-II program were successful in a general sense. But this policy analysis will look for the greater lessons learned in technology transfer and data policy to ensure that the program is not only generically successful, but that it maximizes the societal value of weather observation and prediction systems through the weather community's allocation of resources for infrastructure and organizational structures. Pielke Jr. (Pielke Jr. 2003) argues that the development of organizational structures within the atmospheric sciences has not kept pace with scientific and technological advances. This policy analysis seeks to find out if the scientific advances of weather information and the management improvements of weather information have indeed maintained parity with one another.

1.4. QUESTIONS ANSWERED IN THIS REPORT

While the following analysis will not address each of the questions specifically, the answers to these questions will "fall out" of the upcoming analysis. The last section will however briefly address each question with a summarized answer.

Legal

- Does the Level-II program comply with applicable laws and directives concerning the dissemination of data collected with public funds?
- Are the providers of Level-II data complying with the rules of their signed Memorandum of Agreement (MOA)?
- Is the Level-II program transparent?

Technical

- Does the Level-II program use the most reliable and cost-effective networking architecture available?
- Is the Level-II program nimble enough to take advantage of advances in data processing and networking technology?

Organizational

- Does the Level-II program satisfy its users?

- Are non-profit organizations the correct vehicle to distribute Level-II data, compared to a FOS option or the use of for-profit organizations with the NIDS program?

- Does the Level-II program provide a clear path of accountability?

- Does the Level-II program provide clear, current, and complete communication between appropriate stakeholders?

These questions are especially important today, as the appropriate use and dissemination of data is closely tied with power and organizational success. Consider that during the three months of hurricane landfalls in 2004, NWS websites received nine billion hits, breaking the six billion record set by NASA after the Mars rover landing (Fallows 2005). And during the landfall of Hurricane Katrina, The Weather Channel received 7 million unique visitors to its website on one day alone and took home the crown for most popular news website during the month of September logging 31.5 million unique visitors and beating out sites like MSNBC.com and CNN.com (Whelan 2005). The age of digital information is here to stay and as demonstrated by the volume of interest in weather-related content, whoever controls the data has the power and is also the economic driver for the growing provision of weather services.

2. SETTING THE STAGE

2.1. WHO ARE THE MAJOR PLAYERS?

This section will present an overview of the organizations involved in the collection and distribution of Level-II data. A more complete historical perspective is presented in section three of this report.

The NWS operates 121 NEXRAD sites and data from these radars feed into local Weather Forecast Offices (WFO) across the country. In addition, the NWS collects Level-II data from 13 NEXRAD sites operated by the Department of Defense (DoD). Once the Level-II data arrives at the WFOs, it is passed to one of four regional Headquarters (HQ) offices; Eastern Region, Southern Region, Central Region, and Western Region. From these regional HQs, the data is passed through a GigaPoP portal into the Internet2 Abilene (Internet2) network. Internet2 is a high-speed network sponsored by major universities working in partnership to deploy advanced network applications and technologies. The GigaPoP consists of a sub group of universities in a specific geographic area that provide access to Internet2. NOAA/NWS maintains affiliated memberships in several GigaPoPs so that the Level-II data collected at regional HQs can be transferred to Internet2 (NWS 2004b). To recap, the NWS operates the radars and collects the Level-II data centrally at one of four regional HQs. The NWS then passes this data into the Internet2 network.

The data from all four regional HQs spend only a fraction of a second on the Internet2 network until it is received at one of four Top-Tier sites. Because the data is on the Internet2 network at this point, the only way to tap into this data is to be a member of the network, which is limited to major Universities and research entities (for-profit organizations are allowed membership, but they must join to promote the development and deployment of advanced Internet applications rather than just to consume data) (Internet2 2005). Four University/research Top-Tier sites take the Level-II data from the Internet2 network: The University of Oklahoma (via their non-profit arm, Integrated Radar Data Services or IRaDS); Purdue University; The University of Maryland; and the Education and Research Consortium of the Western Carolinas (ERC).

These top tier nodes are then charged with providing the Level-II data to academic, research, and for-profit users, who may then pass the data on to still more users. A central concept in the provision of Level-II data is that the data be freely disseminated to non-profit users and disseminated to for-profit users at no more than the cost of dissemination. Thus, the Top-Tier sites provide the data to non-profit users for free and charge cost-recovery fees to for-profit users.

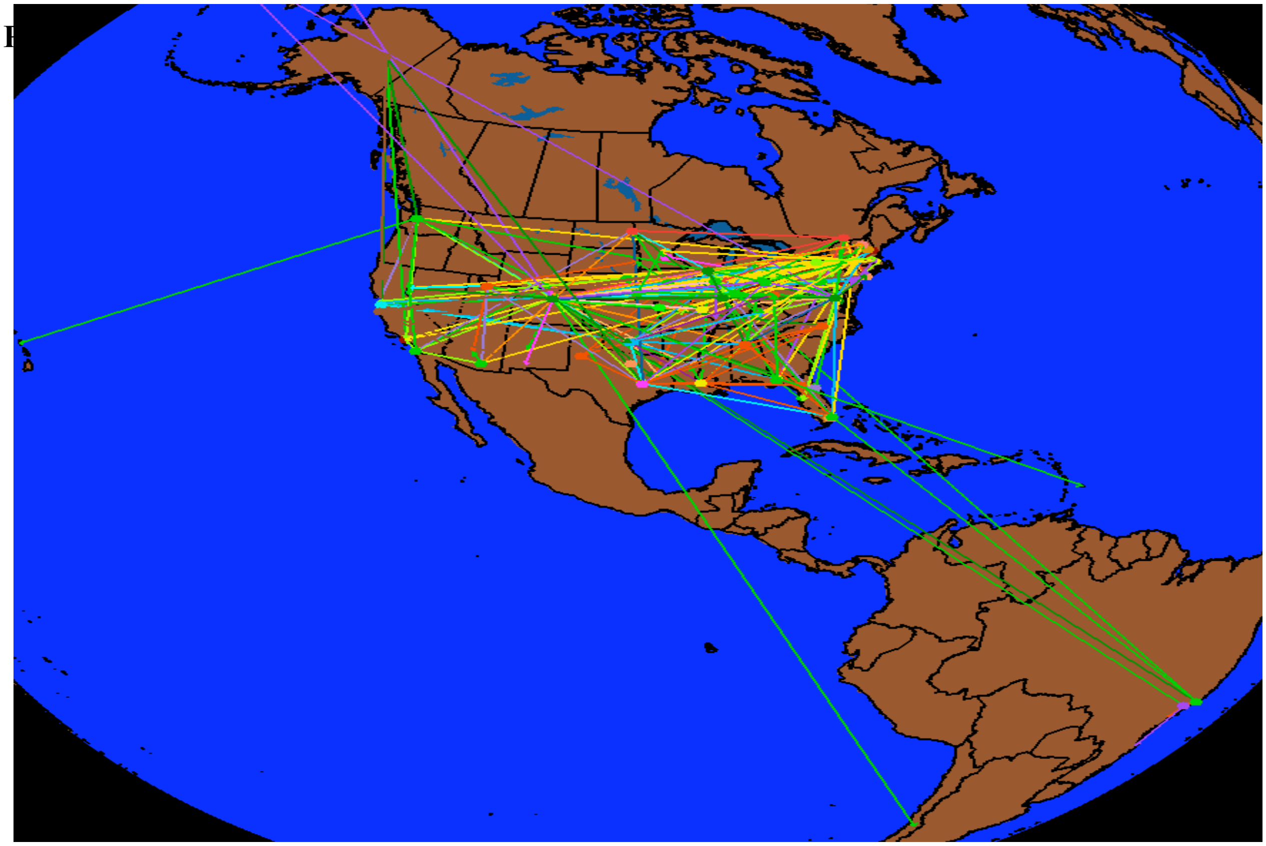


Figure 2: Unidata's IDD moves information across the world for free.

Another key player in the Level-II dissemination program is Unidata, an organization with the University Corporation for Atmospheric Research (UCAR). Unidata exists to serve the university and non-profit research community with data and visualization tools. Through over 20 years of development, Unidata created the Local Data Manager (LDM) software to ingest and disseminate streams of data. Each computer throughout the Level-II dissemination pathway runs the LDM software, which is the vital component to make this entire system function. Further, Unidata's LDM software moves data throughout the U.S. and the world on the Internet via the Internet Data Distribution (IDD) network of computers running LDM software, seen here in Figure 2.

The 'final' point for the Level-II data is the archival system at the National Climatic Data Center (NCDC) in Ashville, N.C. Level-II data is passed from the Top-Tier site at ERC to NCDC for archival. Although NCDC is the official archival site, Texas A&M University (TAMU) supports a secondary archival system at their own expense that keeps a continuous 30-day store of Level-II data. During the late summer of 2005, nearly 20% of the Internet hits to the TAMU radar server came from NCDC, where for some reason the original archival failed for part of the data (Creager 2005).

To put the entire system in perspective, Figure 3 outlines the flow of data from the individual NEXRAD to end users and the final archival site.

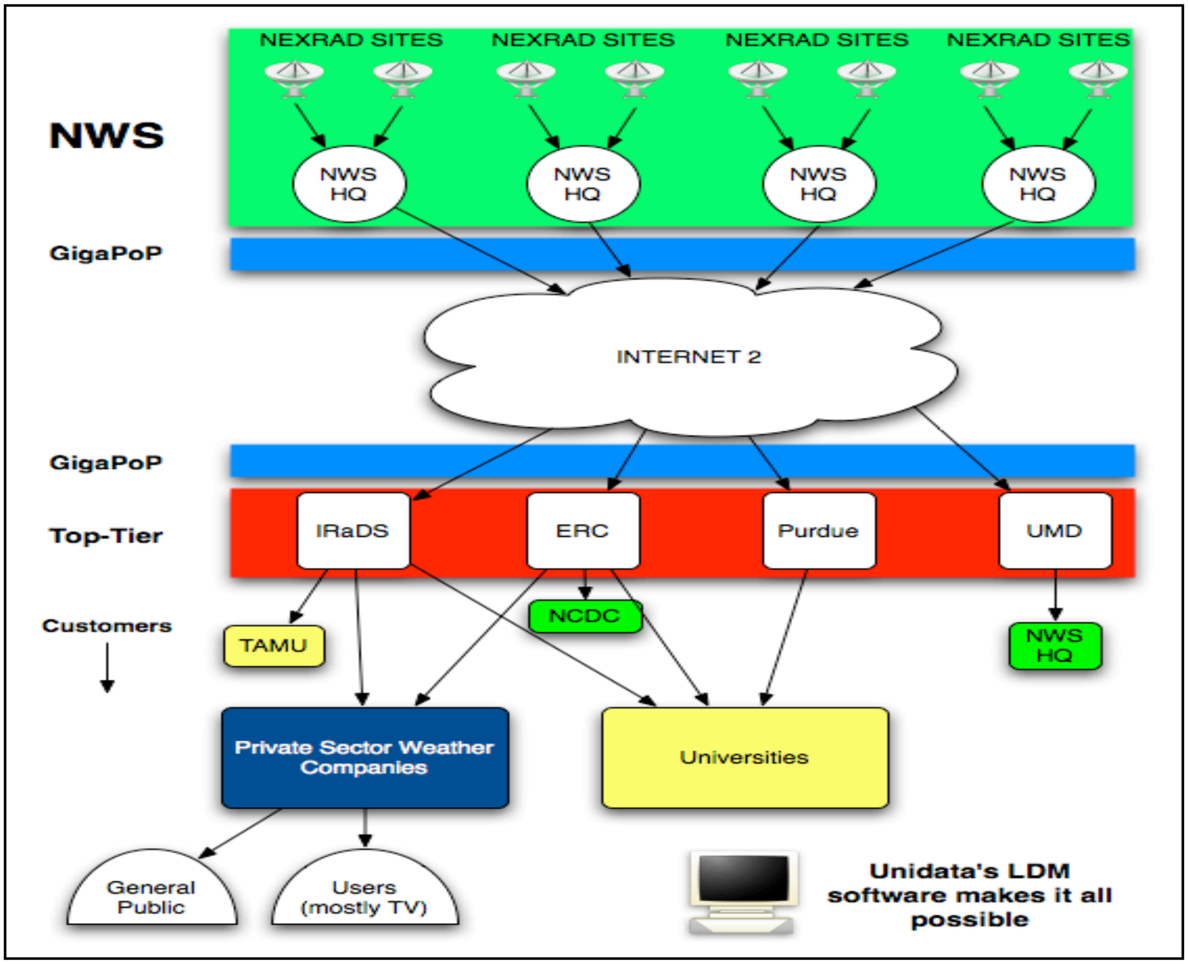


Figure 3: The current layout of the Level-II data dissemination system. The feed from the UMD Top-Tier site to NWS HQ is not discussed here, but will become important in the evaluation of future system architectures presented in section 4.

2.2. WHAT DOES EACH PLAYER EXPECT?

Before exploring the development of the Level-II system and subsequently evaluating the system, it is important to understand each organization's expectations for the Level-II system and also each organization's core drivers. Table 2 outlines these expectations and drivers, and whether conscious or subconscious these characteristics guide action in all but the most altruistic of cases.

Organization	Expectations for Level-II	Organizational Drivers
NWS	>95% reliability; <60 sec latency; system compliant with federal information policies	Adhering to gov't policies; meeting requirements; open access to information; cost-effectiveness
Internet2	Uses relatively low bandwidth; facilitates better weather modeling at Universities	Advance internet technology; advance internet applications
Top-Tier	Receive reliable feed to pass to mission-critical users; competitive market for Level-II data;	National prestige; link with industry and users; regional economic development
Private Weather Companies	Reliable feed for mission-critical environment; rapid response/communications about data outages; level playing field	Competitive advantage with new products; premium charges/new customers for new products to increase profits
Universities	Reliable feed for real-time modeling research; easy archive access	Increase research funding; more research successes with new technology
Users (mostly TV)	New product provides competitive advantage; cost savings or new customers/increased revenue	Profits; say on the cutting edge in technology
General Public	Improve forecast accuracy; better visualization of weather	Save life and protect property; maximize my investment in public infrastructure
TAMU	Reliable feed for real-time modeling research; redundant archival system	Altruistic (TAMU paid for own network equipment for backup system with no current cost recovery scheme)
NCDC	>95% reliability; <60 sec latency; system compliant with federal information policies	Adhering to gov't policies; meeting requirements; open access to information; cost-effectiveness
Unidata	Free and open access to data for university community	Funded by NSF to serve universities

Table 2: Although all stakeholders want reliable data, their motivations for this shared objective are very different.

2.3. HOW DO THE PLAYERS INTERACT?

Although the network diagram depicted in Figure 3 appears to show a long process from the NEXRAD to the end user, in reality this time is usually less than 10 seconds and is often only a few seconds. The LDM software and networking protocols are automated, so no user input is generally needed on a daily basis. Overall, if the system works as it should, none of the stakeholders shown in Figure 3 or described in Table 2 ever need to talk with one another to ensure continual operations.

However, the system doesn't always work as planned, and as provider/user relationships evolve, the stakeholders often communicate their issues and opinions to the other stakeholders. The only formal and systematic means for communication is through the NWS' Family of Services (FOS) meetings, which are held semi-annually. These meetings provide an opportunity for all involved with the Level-II dissemination program to learn of updates affecting the system as well as voice their opinion concerning changes that should or should not be made.

Beyond the FOS meetings, Tim Crum at the Radar Operations Center (ROC) spearheads most of the formal communications. Sometimes these communications employ a push strategy (emails), but mostly use a pull strategy (updated documents at this stakeholder-accessible website: http://www.roc.noaa.gov/NWS_Level_2/). Numerous people within this Level-II system mentioned that the community is sufficiently small so that informal communications (phone calls and emails when necessary) is not a bad option. The use of Top-Tier sites as a communications filter also seems to work well for most users, since the Top-Tiers serve as a knowledgeable link who can determine what information is relevant to provide to users and what user comments are relevant to provide to the NWS.

2.4. EACH PLAYER AND THEIR SPAN OF CONTROL

As Table 2 suggests, all stakeholders involved in the Level-II program are interested in the reliable provision of data, but each stakeholder does not have the same span of control over the resources that enable the Level-II data feed. Internet2, the Top-Tier providers, and the private sector firms and Universities that use the Level-II data are all important links in the system, but the system would not exist without the resources of the NWS. To this end, it is the NWS that holds the key to the Level-II data and this agency was the one that gave the key its final turn to unlock the treasure chest of data. To the credit of the NWS and their employees, they worked with all stakeholders interested in Level-II data and attempted to provide a data dissemination service that pleased the most number of people for the greatest amount of time.

There is no reason to think that the NWS will adjust their resources in any way to degrade the level of service they are providing within the Level-II program, but because the power to control program resources is limited to just one stakeholder (the NWS), it is immensely important to ensure that the decisions of this stakeholder reflect the maximized value of the common interest. The NWS controls the radars themselves, the links from the radars to the WFOs, the links from the WFOs to the regional HQs, and the links from the regional HQs to the local GigaPoPs. Because of this monopolistic but necessary control over the system, the NWS faces great pressure from all other stakeholders who attempt to advocate for their own interests. Sometimes the interests of all stakeholders align, and other times they do not. But the certain aspect is that in most cases, it is up to the NWS to accept user feedback, consider the affects of any policy or resource change on the individual stakeholders and the society as a whole, and then act on a decision. This reliance and focus on the NWS is unfortunate because it detracts attention from areas for improvement that are actionable from the weather community as a whole. Nevertheless, the constant focus on the NWS arises because this agency holds the key to the data and the wealth and value that this data will create. Whereas the other stakeholders' span of control is more limited to certain geographies, products, or customers, the NWS' span of control is overarching over the whole Level-II program. This is not a criticism of or encouragement for the NWS but rather addresses a fact of the current system, which puts even more pressure on the NWS to 'get it right' the first time rather than a slow trial and error process.

3. UNLOCKING THE TREASURE CHEST

3.1. WSR-88D: FROM INSTALLATION TO CRAFT

As the NWS rearranged its resources and modernized in the late 1980s, a cornerstone of this restructuring was the installation of new radars that would yield nearly complete coverage of the United States. These new radars, deemed WSR-88D where 'D' stands for Doppler, became the single pieces of the overall radar network known as NEXRAD, which stands for NEXt generation RADar (Baer 1991). The radars were not stand-alone towers but rather came in a package of new pedestals, transmitters, dishes, and processing units to collect raw data from the radars and turn this raw data into useful products. The Radar Data Acquisition (RDA) unit captured the digital Level-I and Level-II data from the radar, the Radar Product Generator (RPG) took the digital output from the RDA and generated 'picture products' known as Level-III data, and the Principal User Processor (PUP) displays and distributes these products, seen here in Figure 4.

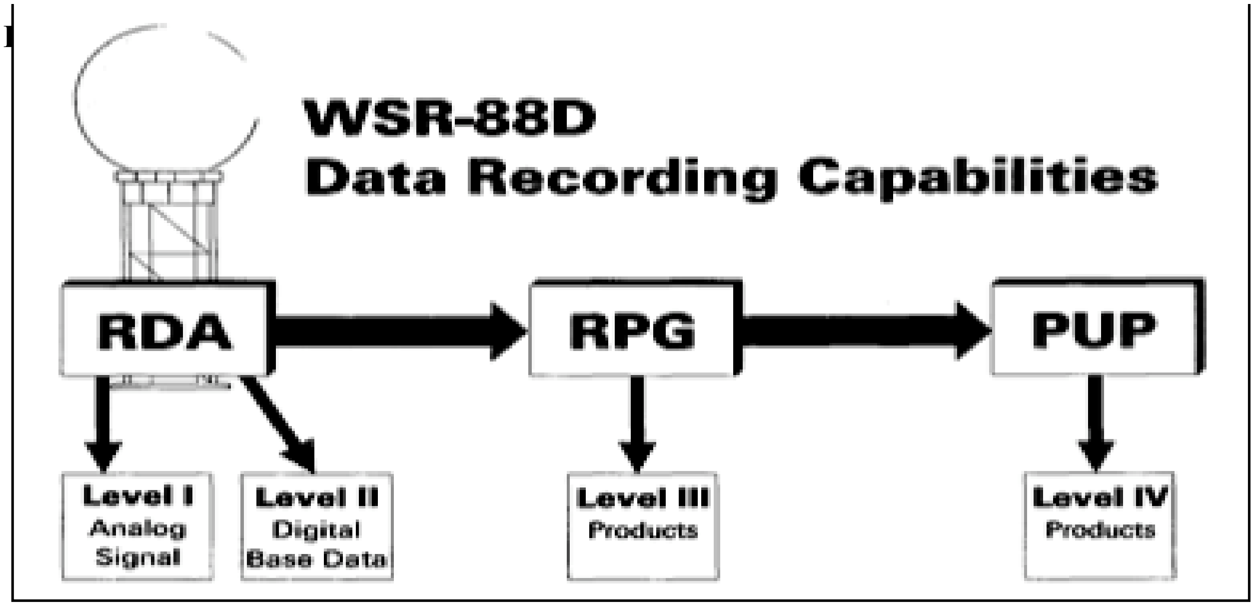
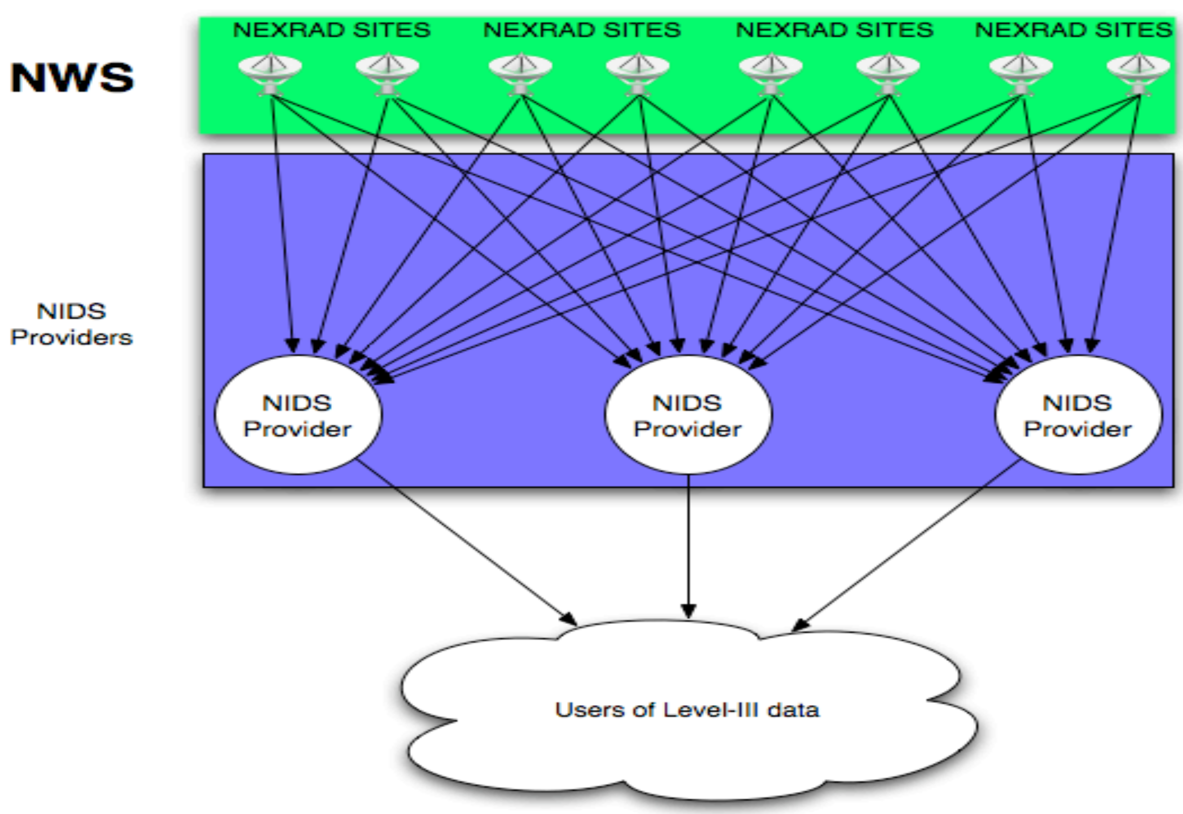


Figure 4: The flowpath of data from the NEXRAD network installed in the late 1980s and early 1990s (Crum; Alberty et al. 1993).

The installation and operation of 100+ new radar sites was an important step forward for the provision of weather services in the U.S., and to complete the loop in adding this new technical capability, the NWS needed to figure out a way to archive and transfer the Level-III products to interested users. For the archival portion, the NWS configured the system to record the Level-II data on to 8mm tape cassettes, figuring that each radar site would generate approximately 500GB of Level-II data per year (Crum; Alberty et al. 1993). These Level-II data cassettes were transported to NCDC where they would remain. To archive the Level-III data, the NWS used 5.25" optical disks.

The transfer of Level-III products involved a somewhat more complicated vehicle called NIDS – NEXRAD Information Dissemination Service. Initially, the NWS had no plans to transmit the radar data to users outside the NWS. Then after numerous comments from stakeholders, the NWS designed four



open ports on the RPG for external users to obtain

Figure 5: Overview of the NIDS Level-III dissemination system. This system was operational from the first installation of the WSR-88D until January 1, 2000.

access the Level-III data. On July 24, 1990, NWS Director Dr. Elbert W. Friday signed three identical NIDS agreements with Alden Electronics Incorporated, Kavouras Incorporated, and WSI Corporation. This agreement specified that the NIDS providers must connect to every NWS radar, centrally collect the Level-III data, and then distribute the data to users. No restrictions or limitations were placed on the NIDS providers, who could sell the data from each or all of the radars to users. The NWS hoped that through competitive market forces between the three NIDS providers, prices for the Level-III data would stay 'reasonable' and this seemed to be the case (Johnson October 7, 2005). The general scheme of the NIDS system is outlined in Figure 5.

The NWS originally awarded the NIDS agreements through September of 1999. An important distinction is that these agreements are not contracts – because the NIDS providers only reimbursed the NWS for the cost of operating the NIDS program and maintaining the external ports on the RPG and never paid for the cost of the data stream. The vendor who installed the radars supplied four external ports because the NWS thought that this was an important number to ensure competition among NIDS providers. In reality, there were only three NIDS providers for most of the time, since a fourth providers was added but this addition coincided with the one of the original NIDS providers leaving.

Based on the technology available at the time, the NIDS program was a pretty good approach. The NWS set an operational standard of 96% availability for the radars, meaning that the radars would be down no more than 4% of the time due to unscheduled failures. On the other side, the NWS agreement directed the providers to supply full-time, continuous, and simultaneous connections to all commissioned WSR-88D sites. The NWS charged the providers a one-time connection fee of $1,357 per radar site and a yearly fee of $1,395 per site that decreased to $444 per site as the Operations and Maintenance costs declined. Although the major costs in this system were the telecommunications costs paid by the providers (~$250,000-$500,000 per year), the overall NIDS system worked well from the time the first radar that went online to its eventual termination on January 1, 2000 (Carelli October 7, 2005). NIDS allowed the NWS to focus on just the radars and the private sector to take care of the dissemination of the data, which was a good solution based on the technology available in the early 1990s.

In the late 1990s, the NWS enacted a requirement to centrally collect the Level-III data from each of the radars. This action was now technically possible with the development of the Advanced Weather Processing System (AWIPS) and the associated telecommunications infrastructure. A new system, called the Radar Products Central Collection/Distribution Service (RPCCDS) centrally collected the data starting in the year 2000. However, the NIDS contract was extended from its original end date of September 1999 until January 1, 2000 to account for the delay in the operational transition to RPCCDS.

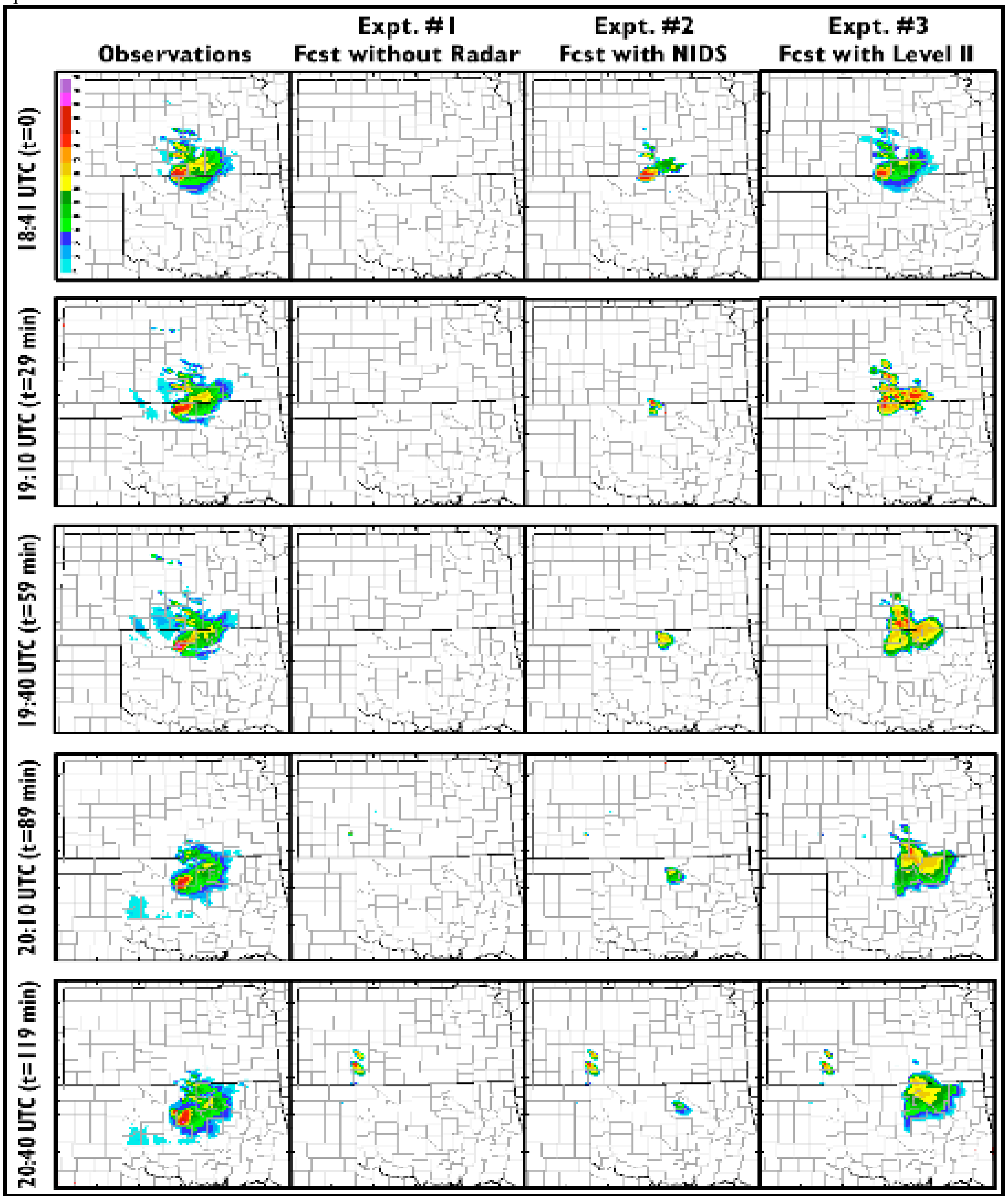
The NIDS dissemination system worked well at the time but would now be impractical and illegal to duplicate. Bandwidth increases allow the NWS to collect information at WFOs and regional HQs, eliminating the need to install external communication lines to each radar. Further, the NIDS providers had mixed feelings of the termination of the NIDS program. On one side, they enjoyed a monopoly in the distribution of the data and they also controlled the downstream data through specific and customized resale agreements with their customers. On the other side, the communications cost to the NIDS providers were significant and the termination of these costs saved the providers money. In the legal sense, current government information policies (discussed further in section four) prohibit exclusive franchises on data in favor of open and unrestricted access. In addition, the NIDS system provided many accounting challenges for special subscribers, where were generally other organizations (Unidata, Canadian weather service, etc) who should receive the Level-III data for free. Since the only way to get the data was through the NIDS providers, the NWS offered the exempt organizations 'coupons' to 'pay' for the data from the NIDS providers. Although this scheme worked, it was challenging and time consuming to implement (Johnson 2001).

As the NWS was working on the RPCCDS system in the late 1990s, Dr. Kelvin Droegemeier at the Center for Analysis and Prediction of Storms (CAPS) worked tirelessly to initiate support for an experimental system to disseminate and archive the Level-II data in real time. These efforts by Dr. Droegemeier set the foundation for the CRAFT project.

3.2. CRAFT: FINDING THE KEY TO LEVEL-II DATA DISTRIBUTION

Beyond the immediate forecasting use of the Level-III data, researchers began to realize the need for assimilation of the Level-II data into numerical weather prediction models. Because the Level-III is a low-resolution snapshot of the state of the atmosphere, the utility of this information in weather models is not as high as the Level-II data.

The Center for Analysis and Prediction of Storms (CAPS) showed the value of the Level-II data with a case study of the Lahoma supercell of 17



August, 1994. CAPS ran three numerical simulations of the supercell using different input data. In all cases, the Rapid Update Cycle (RUC) model provided the background environmental conditions. The first simulation initialized with no radar data, the second simulation initialized with Level-III radar data, and the third simulation initialized with Level-II data (Droegemeier; et al. 1999). The results are striking and provide a justification (Figure 6) for the use of Level-II radar data to initialize numerical weather models.

Figure 6: The use of Level-II radar data improves the short-term modeling of the Lahoma Supercell on 17 August 2004. Each row is a snapshot in time (from top to bottom). The left column shows the observed radar; the following columns are described above.

The justification of the value of Level-II data for research and modeling purposes is an important step, but a key problem remained: How to transfer the Level-II data from the radar in real-time to a weather model, and how to reliably archive the Level-II data for research use at a later date? To solve this problem, CAPS, Unidata, and other academic and government organizations collaborated on CRAFT:

> The US National Weather Service (NWS) recently completed the installation of...WSR-88D (NEXRAD) Doppler Radars. Although these systems originally were designed without archival capability for the full-volume, full-precision Level II (base) data, an archival strategy based upon 8 mm tape technology eventually was implemented. Since 1992, the NCDC has been archiving the data tapes and using the same media to provide base data to the national community. Although an innovative and satisfactory solution several years ago, the tape system is extremely human-resource intensive, costly, inefficient, and unreliable.
>
> In an attempt to begin addressing the long-term needs for WSR-88D base data archival, and in light of the compelling need for real time access to base data for use in a variety of applications, especially numerical weather prediction, the CAPS at the University of Oklahoma joined forces in 1998 with ...Unidata..., the University of Washington, the National Severe Storms Laboratory (NSSL), and the WSR-88D Operational Support Facility (now the Radar Operations Center - ROC) to establish the **Collaborative Radar Acquisition Field Test (CRAFT).** *The principal goal of CRAFT is to demonstrate the real time compression and internet-based transmission of WSR-88D base data from multiple radars with a view toward nationwide implementation.*
>
> (Droegemeier 2002b)

The visionary leaders of CRAFT (Dr. Kelvin Droegemeier at CAPS and Dave Fulker at Unidata) not only outlined a significant problem and provided the motivation to seek solutions, but they also did this with the foresight to see the end of the tunnel. The title of a presentation by Dave Fulker succinctly captures this foresight: "A CRAFT Model that Evolves from Experimental to Operational, Built on Early Private-Sector Participation" (Fulker 2002).

Comments from people in all sectors of the weather enterprise communicate that CRAFT was an overwhelming success, both as a technical research project and from a management standpoint. CRAFT involved any and all stakeholders who wished to be involved, it kept all stakeholders involved through numerous meetings (see these websites for more: http://kkd.ou.edu/craft.htm, http://www.caps.ou.edu/CAPS/craft.html, http://www.unidata.ucar.edu/projects/craft/index.html), and moreover the CRAFT leaders provided numerous options and alternatives to stakeholders and allowed all to weigh in on their preferred option. Further, CRAFT was planned from inception to involve the private sector and worked with an end goal in mind – to transition the research into operations for the good of the weather enterprise and external users. On the technical side, CRAFT demonstrated the ability to compress Level-II data and use the LDM technology from Unidata to disseminate data from the WSR-88D radars back to the CRAFT central servers at CAPS (located at the University of Oklahoma (OU)) and then out to users.

CRAFT started with eight radars from the southern Great Plains and through continuous improvement established a network with 67 radars by September of 2002. The collaboration between OU and the ROC ensured that technological improvements within CRAFT transitioned to the radars themselves, and collaboration between OU and the academic, government, and private sector community ensured that the benefits of real-time dissemination and archival of Level-II data reached user organizations. By the September 26-27, 2002 CRAFT stakeholder meeting, however, the project reached an important transition period. CRAFT solved many of the basic science questions about the value of Level-II data and the compression and transmission of the data, so the science justification of the project dwindled. From 1998 to 2002, eight out of ten funding sources for CRAFT were from the government or academic sectors which were more interested in funding the research aspects of the project rather than the operational and maintenance aspects (Table 3).

Funding Source	Amount	Period
OK State Regents for Higher Education	$ 210,000	1998-1999
NSF EPSCoR	$ 46,000	1999
NOAA/ROC	$ 156,000	1999-2002
NOAA/ESDIM	$ 540,000	2000-2002
NOAA	$ 474,000	2000-2001
NOAA/HPCC	$ 198,000	2001
NOAA/Sea Grant	$ 48,500	2001
NSF	$ 15,000	2001
Partner Match	$ 600,000	1998-2002
Private Sector Direct	$ 150,000	2001-2002
Total	**$2,437,500**	

Table 3: Funding sources for CRAFT from 1998-2002. The majority of funding was from organizations interested in basic and applied science than in operations, which brought CRAFT to a crossroads in 2002 (Droegemeier 2002a).

At this point in 2002, CRAFT supplied Level-II data to seven academic organizations (including UCAR/NCAR), five entities within NOAA, two non-NOAA government organizations, and six firms in private industry. All data was free to government and academic institutions, and was provided at the marginal cost of dissemination to private sector users. Although there was no guarantee of data reliability or 24x7 customer support for users of the Level-II data feed, the high reliability of the CRAFT network architecture and the data transmission from the CRAFT servers to the user organizations via the internet led to a number of organizations with high expectations for current and future data feeds. Specifically, the private sector asked for latencies of no more than 10 seconds and data reliability at the 99.99% level (Droegemeier 2002a). With these users and user requirements in mind, the project formerly known as CRAFT began a slow yet directed transition into NWS operations.

Although this report discusses CRAFT as part of the full analysis of the Level-II program, the short attention paid to CRAFT is in no way a proxy for the project's importance in the overall development of the Level-II system. Without CRAFT and the few but outspoken and motivated leaders at its helm, there would be no real-time dissemination and archival system of Level-II data. CRAFT took the Level-II data archive at NCDC from 65% complete using 8mm tapes to near perfect archival using a completely digital stream. And perhaps most impressive, CRAFT transitioned a NEXRAD network not designed with any real-time dissemination or archival capability for Level-II data and made these functions operational on nearly half the network in only four years and with limited and piecemeal funding. CRAFT is an exceptional success story and this paper now moves to examine the transfer of CRAFT technology to operational use in the NWS.

3.3. TECHNOLOGY TRANSFER: CRAFT TO NWS OPERATIONS

Because of the close collaboration between the NWS and the CRAFT team, the NWS was already considering options to integrate CRAFT technology and processes into operations by early 2002, over a year before the first official stakeholders meeting sponsored by the NWS and nearly two years before an operational solution went live. Based on existing CRAFT architecture and the need to incorporate over 130 radar feeds into the operational Level-II system, the NWS proposed ten options to handle the data (Crum August 11, 2002). Although most of these options were never presented at subsequent stakeholder meetings, the fact that the NWS was planning so far in advance for a technology transfer opportunity speaks highly of Dr. Tim Crum of the ROC and the decision makers in the NWS and CRAFT who were so intent for the Level-II real time feed to cross the 'valley of death' from research into operations.

Another aspect of the pre-planning needed to bring research into NWS operations is the stated requirement by the NWS for the data. The NWS cannot spend tax-payer money on operations that are not required. Thus, for NWS to operate the real-time dissemination and archival system, they needed to initiate requirements for the use of Level-II data. Several NWS staff wrote these requirements in early 2002 and the document was reviewed and approved soon after. There are two major metrics in these requirements:

- Level-II **reliability must be at least 95%.** This requirement is for the archival of data at NCDC
- Level-II **latency** (measured between the RDA and receipt at final location) must be **less than 60 seconds** to support rapid computer model updates at the National Center for Environment Prediction (NCEP)

These requirements direct priorities and resources within the NWS, as Dr. John Hayes, Director of the

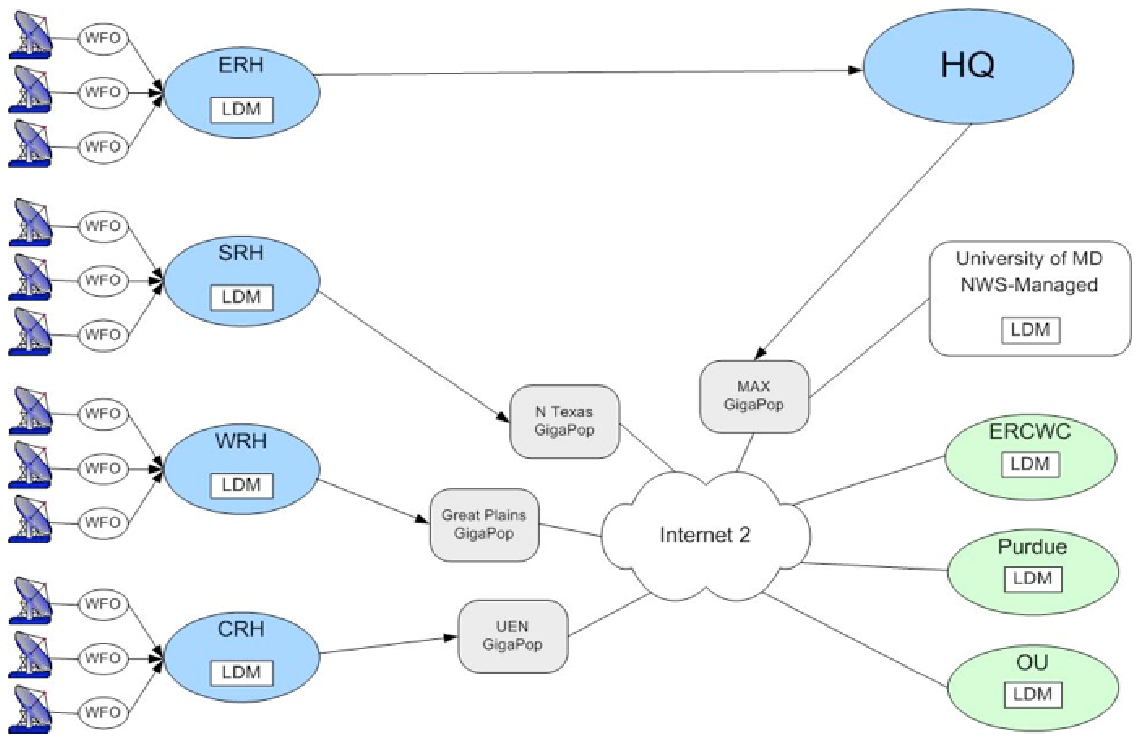


Figure 7: System architecture of Level-II data dissemination (Sandman June 23, 2005).

NWS Office of Science and Technology (OS&T) mentions at the NWS Level-II stakeholders meeting on June 18, 2003: "...Dr. Hayes emphasized that the network is being implemented to meet NWS requirements...[and]...where changes can be made at no or little additional cost to accommodate external need, the NWS will seriously consider them" (Crum 2003).

In addition to internal NWS requirements, the federal government also has guidelines that direct the flow of publicly funded information. Whereas the Omnibus Budget reconciliation Act of 1990 (15 U.S.C. 1534) urges government agencies to charge "fair market value" for data, this changed with the move to open dissemination of information. The Paperwork reduction Act of 1995 replaced the "fair market value" concept with "open and unrestricted access at cost of dissemination." Further, the Office of Management and Budget (OMB) Circular A-130 prohibits exclusive franchises (like that developed under the NIDS program) and encourages, "...agencies to use all relevant technologies, particularly the Internet, to maximize dissemination of taxpayer-funded information to all" (OMB 1996). These guidelines push the NWS to opt for open, unrestricted access to the Level-II data at no more than the cost of dissemination.

The June 2003 NWS stakeholders meeting put four options on the table for the dissemination of the Level-II data.

1. An existing non-profit (i.e. Unidata) serves the Level-II data to users

2. A jointly owned/operated cooperative supported by the private sector supports data feeds to users

3. Family of Services (FOS) option. The NWS centrally collects the Level-II data and makes this available much like the Level-III data

4. Several Universities serve as dissemination nodes using the Internet2 Abilene network to pass the Level-II data to all users

Comments from the user community following the June 2003 NWS stakeholder meeting (NWS 2003) generally supported the third and fourth options, citing the costs and legal issues involved with option number two and the unlikely scenario that Unidata would want to transition into an operational center for option number

Service Level	Features	Monthly Cost	Yearly Cost	Billing
Platinum	All available NWS WSR-88D (NEXRAD) radars	$1,875.00	$22,500.00	Quarterly
Gold	Up to one-half of all available NWS WSR-88D (NEXRAD) radars	$1,218.75	$14,625.00	Quarterly
Silver	Up to one-fourth of all available NWS WSR-88D (NEXRAD) radars	$750.00	$9,000.00	Quarterly
Bronze	Up to one-tenth of all available NWS WSR-88D (NEXRAD) radars	$468.75	$5,625.00	Quarterly
Platinum with ECM*	Platinum with Enhanced Client Monitoring*	$2,343.75	$28,125.00	Quarterly
Gold with ECM*	Gold with Enhanced Client Monitoring*	$1,523.44	$18,281.28	Quarterly
Silver with ECM*	Silver with Enhanced Client Monitoring*	$937.50	$11,250.00	Quarterly
Bronze with ECM*	Bronze with Enhanced Client Monitoring*	$585.94	$7,031.28	Quarterly

Customized Support	Features	Cost
Field Support and Installation	Customized installation of computer ingest hardware and LDM system (network must be provided)	$200/hour plus expenses
Expert Training	Customized training on use of Linux, LDM, NEXRAD Level II data decoder, other software	$1,500/day plus expenses

Figure 8: IRaDS cost structure, as viewed on November 1, 2005 from https://www.radarservices.org/cost.php.

one. Based on this feedback, the NWS selected the fourth option because it cost less than a FOS option, and since the Level-II distribution scheme needed to use the Internet2 Abilene high speed network to move the large amounts of data, it made sense to involve the University and research sector since Internet2 was primarily supported by stakeholders from this sector. The following graphic (Figure 7) illustrates the proposed Level-II dissemination system, which is still in effect as of this writing.

Once the NWS settled on the above architecture, the NWS along with Unidata proceeded to develop a Call for Participation to select two Top-Tier sites. Although Figure 7 shows four Top-Tier sites, two sites were already selected based on NWS requirements. The University of Maryland was a necessary link between the NWS headquarters in the Washington D.C. area and the Internet2 Abilene network. In a similar vein, the Education and Research Consortium of the Western Carolinas (ERC) served as the link for NCDC to the Internet2 Abilene network. That left two Top-Tier nodes for selection through the Call for Participation. Four Universities responded to the call, and a team of Unidata and NWS personnel selected Purdue and the University of Oklahoma.

Both Universities signed the Memorandum of Agreement (MOA) with NWS by early April 2004 and through a press release on the April 13, 2004 (NWS 2004c), the Level-II data dissemination system went live through the Top-Tier architecture developed by the NWS (NWS 2004a). Through the entire transition from CRAFT to the operational start of the Top-Tier architecture, Tim Crum of the ROC sent email communications to all the participants in CRAFT and the NWS stakeholder meetings. Through these emails and presentations at FOS and other meetings, the stakeholders received timely updates on the progress of the Level-II distribution system.

3.4. CURRENT STATUS AND FUTURE PLANS FOR LEVEL-II DATA

According to the Autumn 2005 edition of NEXRAD Now, 10 federal organizations, 22 Universities, and 12 private sector firms use real-time Level-II data, and about 100 TV stations receive products from the private companies (Crum 2005). As of November 2005, the NWS is supporting Level-II data feeds from 134 radars, and also supports a real-time website that monitors the reliability and latency of the data, available at this URL: http://weather.noaa.gov/monitor/radar2/. One NWS official remarked that in the grand scheme of things, the NWS portion of the Level-II program has done well with few if any additional resources in the 18 months since the operational start of Level-II in April, 2004.

While most Top-Tier sites agree that the current Level-II system is continuously improving, there have been problems since the MOAs were signed. One major issue arose at the January 2005 FOS meeting held in conjunction with the American Meteorological Society (AMS) annual meeting in San Diego. At this meeting, the NWS proposed to offer a FOS option for the Level-II data and presented a powerpoint slide which projected possible costs to be about ($57,000 / # of users). If a number of users signed on to the FOS option, then their costs would be substantially less than the cost of the IRaDS service, listed below in Figure 8 from their publicly accessible website.

Beyond this issue of cost, the Top-Tier providers were upset that the NWS would offer a FOS option because the FOS option would be in direct competition with the existing Top-Tier sites. Although the Top-Tier sites operate on a cost-recovery/non-profit basis they operate in a market that was set-up with the initial MOA, and the addition of a FOS option would grossly change the market structure. To the credit of the NWS, they listened to the Top-Tier provider's complaints and rescinded the FOS proposal soon after the January 2005 meeting.

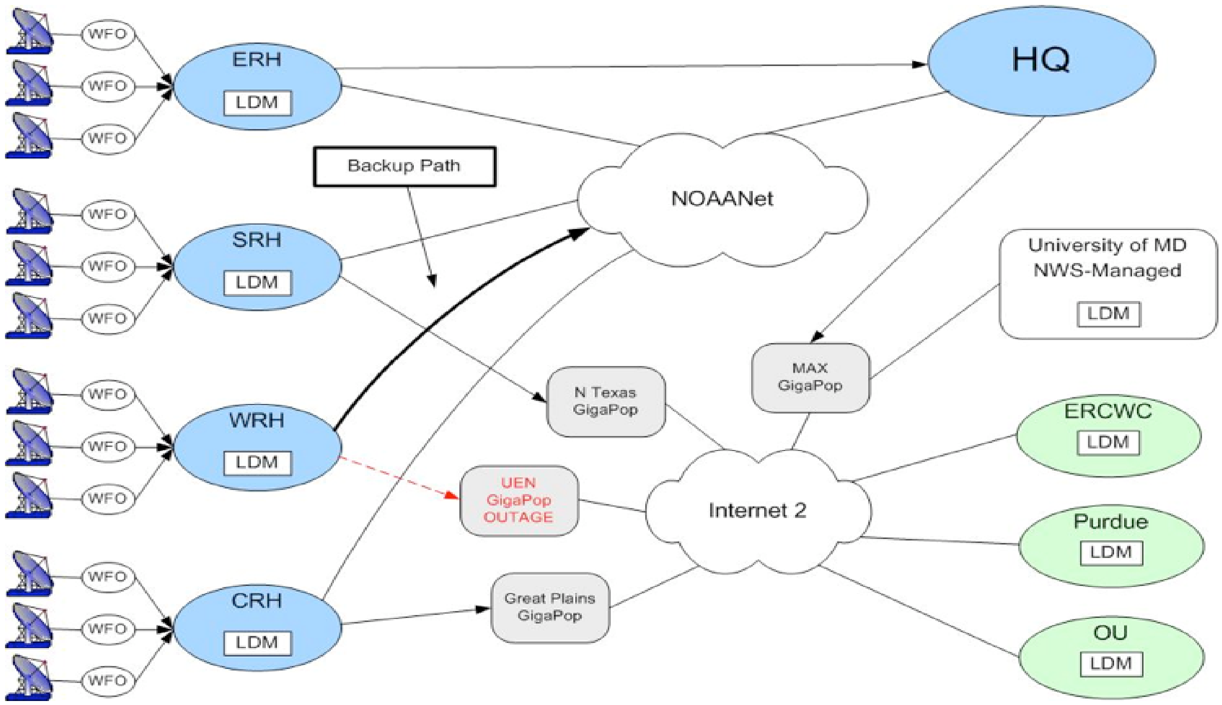
Beyond this discrete problem, Top-Tier providers and users of Level-II data have complained that data reliability is a problem, especially along the path controlled by the NWS from the WSR-88D site through the WFO and regional HQ. The following letter from a Top-Tier provider to the NWS nicely summarizes the comments of the community of Level-II users:

Monthly Performance Data

Month	Total Outage Minutes	Availability
June 2004	40	99.98%
August 2004	6,288	99.94%
September 2004	2,880	99.93%
October 2004	10,200	99.80%
November 2004	32,514	99.42%
December 2004	11,012	99.80%
January 2005	255,050	95.53%
February 2005	45,912	99.11%
March 2005	3,886	99.93%
April 2005	33,060	99.40%

Figure 9: Presented at the June 2005 FOS meeting (Sandman June 23, 2005).

> "Subsequent meetings with NWS data experts revealed that the initial expectation set by NWS was to offer 95% reliability for Level-II data provisioning on top of a guarantee of 96% reliability for NEXRAD radar sites. Should the university and private sector provisioning achieve a 99% reliability, then the end user expectation for Level-II reliability from a combination of all metrics can only be about 90%. 90% reliability equates to 35 days of outage per year or almost 3 days per month.
>
> It is the *[name omitted]* position that an information system that delivers 90% reliability for the end user has little viability for commerce and protecting life and property. Whereas weather impacts are highly localized,



> we believe radar site-specific metrics for data delivery must exceed 95% and achieve closer to 99% end-user reliability for both commercial viability and protection of life and property.

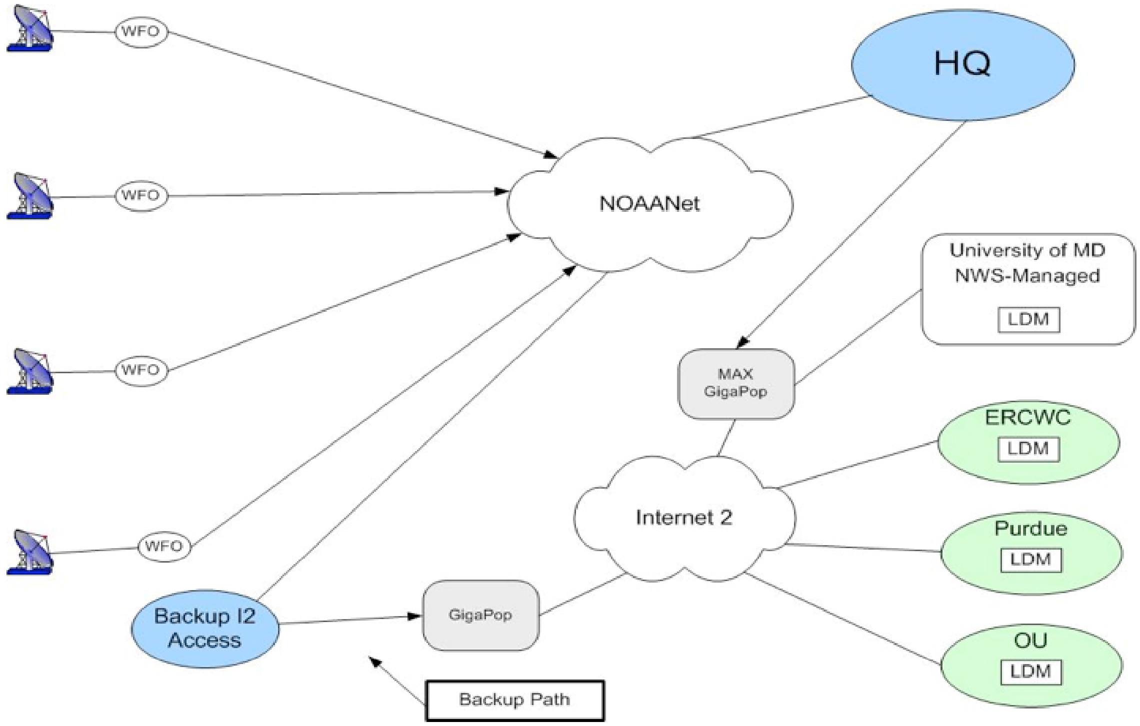
Clearly there is a disconnect in the Level-II system between what the users expect and what the NWS can deliver. Although NWS reliability metrics are often well above 95% and closer to 99% (see Figure 9), the minimum NWS requirement is still 95% set from the original requirements published in 2003.

To be fair, after the delivery of the above statement in June 2005, many Level-II users report that data reliability has greatly improved, although the exact reasoning for this improvement is unknown. Generally, the Level-II network suffers from a single point of failure at the regional HQs – if the server at a this location malfunctions, this stops the data feed for an entire region of radars (25, 28, 39, and 42 radars within each region). Solving this problem could involve better maintenance on the server at the regional HQ or simply better monitoring on the part of the regional HQ staff, and it is unclear which of these factors or other factors has contributed to the recent increase in data reliability. In addition to the reliability issue, some Top-Tier providers and users also commented that they do not have a good understanding of planned maintenance operations on radars that would cause outages and are generally il-informed about the status of upgrades and fixes to the radars.

Staying on the theme of change, the NWS is planning to move to a slightly different architecture by September 2006, and they presented this plan at the June 2005 FOS meeting. The NWS developed requirements for the Level-II data in early 2003, the data feed was never considered operational or in other words a mission-critical feed within the NWS, compared to watches and warnings for instance. This will change by September 2006, and to support the transition of the Level-II data from a requirement to full operations, the NWS will use their own network (NOAAnet) *in addition to* the original Internet2/Abilene network to aggregate and transfer the data, as seen in Figure 10.

Figure 10: The new proposed interim system architecture. The single point of failure problem still exists at the regional HQs, but now there will be redundancy with Internet2 and NOAAnet (Sandman June 23, 2005).

The target system architecture is presented in Figure 11, which shows that communications will go directly from the radar to NOAAnet, alleviating the single point of failure at the regional HQs but creating a single point of failure at NOAAnet. However, since NOAAnet is a



mission critical system and staffed around the clock, in theory the single point of failure problem with NOAAnet will be much smaller than at the regional HQs.

Figure 11: The proposed target system architecture. The single point of failure problem still exists at NOAAnet, but NOAAnet should have a much lower probability of failure compared to the regional HQs and also a quicker corrective response when problems arise (Sandman June 23, 2005).

Through this point, the report has focused on presenting a historical perspective. Following in sections 4 and 5 is the evaluation of the Level-II system as a whole.

4. EVALUATION OF THE LEVEL-II SYSTEM

4.1. GOAL OF THE LEVEL-II SYSTEM

Using a blended foundation of the NRC (NRC 1999) statement and current documentation governing publicly funded information, *the goal of the Level-II distribution and archival system is to **(1) maximize** the nation's investment in weather infrastructure through **(2) unrestricted**, **(3) wide**, and **(4) equitable** data distribution and archive access in a **(5) mission-critical** environment.* The highlighted adjectives indicate constructs in the goal statement, and the following sections will evaluate these constructs. The goal statement listed here incorporates objectives to benefit society as a whole and the weather community in particular while maintaining agreement with current laws governing the dissemination of publicly funded data.

4.2. DO PROBLEMS EXIST?

Based upon the previous sections of this report and numerous interviews with persons in the government, the academic/research sector and Top-Tier sites, and the private sector, the following summarizes the degree to which current events meet the stated goals.

1. Although the nation benefits from the distribution and archival of Level-II data, the nation's investment in the NEXRAD infrastructure is **not maximized** because there is not an organized evaluation of the Level-II program which collects regular feedback, establishes future program priorities, and strives for continuous improvement.

2. The MOA between the NWS and the Top-Tier sites states that "Level-II data will be released without any prohibition for its redistribution or use" (NWS 2004a).

'Ground truth' **confirms the unrestricted distribution of data, which fulfills this goal construct**.

3. This study **cannot directly determine if the Level-II data is widely distributed**. The weather community (providers and users) do not keep aggregate and repeatable metrics to track progress of the market for and use of Level-II data. Further, attempts to obtain this information were nearly impossible due to non-disclosure agreements and competitive advantage concerns that discourage the collection of aggregate data.

4. Through the unrestricted flow of Level-II data promoted in the MOA, situations develop within the system that **could lead to the unequitable** (def: unfair and impartial) distribution of data.

5. The system architecture provides a scalable solution to serve present and future mission-critical interests, although current Level-II **data generally does not meet the mission critical needs** of many users.

4.3. CURRENT TRENDS

1. Although the stated problem calls into question the present level of evaluation and improvement of the Level-II system, this is really a problem of *systematic evaluation and improvement*. The community of Level-II system administrators, providers, and users is relatively small, and does communicate with one another via email and telephone. These informal communications do affect improvements in the system as seen from April 2004 until the present, but these communications and improvements are not done in a regular and systematic way. The semi-annual FOS meetings present a regular forum for discussion of Level-II issues, but again there are no systematic methods to evaluate the program and prioritize improvements. Solely for monitoring and communications purposes, the NWS recently built a real-time webpage to give constant updates about the status of all 134 radars disseminating Level-II data (NWS 2005a).

2. All uses who want access to the Level-II data receive access to the feed. This was true beginning in April 2004 and continues to this day.

3. Like the first problem, this is really an issue of *systematic* metrics to track the growth in the market for Level-II data. All Level-II providers and users contacted for this report agreed that the market for Level-II data is holding constant or increasing, but no stakeholders have collected systematic aggregate data to ascertain just how widely the data flows.

4. The Level-II data feed is free to Universities and research institutions and is provided at the cost of dissemination to private sector or for-profit organizations. Because the data is unrestricted (see point #2 above), any organization or individual is able to receive and redistribute the data. Recently, some organizations or individuals who receive the data for free (either from the Top-Tier providers or from the Universities who receive the data for free) have passed this data along to for-profit entities at no cost. Although this is technically a legal arrangement owing to the "unrestricted" dissemination of the data, it violates the spirit and intent of the MOA which directs that only Universities and research organizations should receive free data. If for-profit organizations are receiving free Level-II data, this is an unequitable distribution scheme. Since April 2004, this problem ebbed and flowed with discrete (i.e. not systematic or planned) instances of this type of unequitable data distribution.

5. The single point of failure problem at regional HQs, "low" requirements of 95% availability, and <60 second latency all point to a system that meets the letter of the NWS requirements but not the mission critical needs of the private sector. According to the Level-II provider IRaDS, nearly 50 regional outages occurred between August 2004 and August 2005. These regional outages averaged over four hours per outage. Moreover, the NWS maintains a webpage

(http://www.roc.noaa.gov/NWS_Level_2/) to provide information for Level-II providers and users, but this "pull" strategy of information dissemination has not met the needs of mission critical users who want more information about planned outages and status updates on current outages. Tim Crum from the ROC employs a "push" strategy to information dissemination with emails to a long list of stakeholders, but these emails are not an operational aspect of the Level-II system.

4.4. WHY ARE THE TRENDS OCCURING?

1. No systematic evaluation and priority setting program exists because the Level-II program is relatively small. Perhaps the NWS feels that improvements are occurring at a comfortable pace and no extra amount of evaluation will help to speed up the process. Beyond the NWS, the providers and users of Level-II data could also implement and/or design such a systematic evaluation, but this group seems to put the onus on the NWS for this type of undertaking.

2. The Paperwork Reduction Act of 1995 and OMB Circular A-130 direct unrestricted access to government information. The MOAs reproduce this type of language, which directs the current trend of unrestricted access.

3. If the NWS, providers, or users are not keeping aggregate data on the use of Level-II information, perhaps no organization would benefit from such statistics. The NWS is interested to find out who it is serving with Level-II data, but again privacy agreements between providers and client organizations prevent easy access to aggregate data.

4. It does not seem that any individual or organization brings the intent to act against the intent of the MOA and provide Level-II data for free to for-profit entities. Rather, comments from users of Level-II data lead to the conclusion that organizations or individuals who receive Level-II data for free pass it on for free in order to make the data as widely available as possible. This is an altruistic reason, yet this altruism potentially violates the intent of the MOA.

5. The lack of a mission critical level of service by the NWS comes down to their requirements. The NWS requirements direct 95% reliability and less than one minute latency. Although the reliability and latency issues improved during the second half of 2005, this is due mostly to the hard work and determination of a few individuals at NWS and the ROC rather than an organization-wide effort to improve the system. All users indicate that the level of service problems stem from the NWS-controlled portion of the network and not the systems run by the Top-Tier providers or the connection reliability of the Internet1 communication link from the Top-Tier providers to the users.

4.5. WHAT WILL THE FUTURE BRING?

1. Without an ongoing evaluation, which involves reaching out to all stakeholders, the NWS will never fully understand the shortcomings and areas for improvement in the system and will not be able to track customer satisfaction to accurately asses the value of the Level-II data. The NWS is planning to upgrade to a new system architecture in September 2006, and although this should increase the up-time of the data feed, without a systematic evaluation, the providers and users of Level-II data will not be able to make a strong case for the value of the data. Further, without an ongoing evaluation that yields quantitative data, opportunities for increased program funding and system improvements will be missed and the value of the nation's investment in weather infrastructure will not be maximized. Qualitative testimonials to system performance and value can provide a means of evaluation, but this type of evaluation is not robust. The MOA says, "NWS seeks to foster the equitable and wide distribution of Level-II data to users in the academic, private, and government sectors." The NWS will never fully understand if it archieves this statement without measuring progress. And without measuring progress, a quantified statement about the value of

Level-II data is simply a guess.

2. Unless government law changes or the MOA is altered after its end date of December 31, 2006, the current unrestricted access to data will continue.

3. Business as usual will likely persist, and the privacy issues will likely keep the collection of aggregate usage statistics at bay.

4. Community policing and/or legal action will likely occur to stop the 'altruistic' distribution of Level-II data to for-profit companies from sites who freely obtain the data. One other aspect that may affect the equitable distribution of data is a future FOS option to distribute the data. When the NWS brings the target system architecture in Figure 11 operational by September 2006, the door to a FOS option will exist and the NWS could exercise this option like it proposed to do at the January FOS meeting.

5. The proposed improvements to the NWS side of the Level-II system should markedly increase data reliability, hopefully to mission critical levels since the Level-II data will rely on the same network as the NWS official watches and warnings. Depending on the internal information needs of the NWS, the communication of planned radar outages and maintenance updates will likely improve as well, owing to the organization's internal requirements.

4.6. OPTIONS TO SOLVE THE PROBLEMS

1. The MOA addresses goals for the Level-II program, and these goals directly correlate with achieving the maximum value of the nation's investment in weather infrastructure. The NWS should partner with the providers and users of Level-II data to measure progress toward the following objectives:
   a) *Increase real time availability and widespread use of Level-II data.* Metrics for this objective include data uptime, planned downtime, unscheduled downtime, latency, volume of data per user, total data volume delivered to users, time for radar in clear-air mode vs. precipitation mode.
   b) *Promote economic and educational development.* Metrics for this objective include number and sector of users, average prices for the data, aggregate revenue from private firms stemming from Level-II data, number of products/services offered by private companies that incorporate Level-II data, number of academic institutions using Level-II data in the classroom, number of students exposed to Level-II data in the classroom.
   c) *Considerable cost savings to the nation.* This is a very ambiguous objective and more work is needed to define a measuring strategy.

   Some may argue that taking the time to measure these variables is a waste of time and resources. However, without some year-to-year measurement of the value of Level-II data, all comments about the data's value is simply lip service. Quantitative measures help to convince those outside of the weather community of the worth of the data, and these measures also help to define priorities for improvement.

   Another impediment to implementing this type of measuring system is the privacy issues of private companies. Like other industry trade groups, the CWSA or National Council of Industrial Meteorologists (NCIM) could work with their members to conduct an aggregate survey to maintain anonymity among the companies.

2. Since the Level-II data is distributed in an unrestricted manner, there is no problem for which to offer a suggested solution.

3. Option number one contains the metrics to assess the wide distribution of Level-II data. Even if the community does not implement all parts of option number one, it should at the very least report aggregate

data on the number and type of stakeholders that use Level-II data in their organization or business. A year-by-year assessment of these aggregate numbers will ensure that the value of Level-II data is communicated to those outside of the weather community. These numbers will also illustrate the wide use of government-funded data in the private and academic sectors, which should help to enlighten the weather community of its own breadth.

4. The Level-II community must work together to ensure that all users of the data comply with the spirit and intent of the MOA. This includes communicating with the 'altruistic' and perhaps not so altruistic users who pass their free data along to for-profit institutions at not cost. The community should pressure these organizations and individuals to stop this practice. The real bottom line is that data distribution is an old business model. Private companies should look to value-added business models, and most do. This is just a note to companies who complain about competing with providers who give data away for free: Although these companies have a legitimate philosophical complaint, they should be able to sell their services not only on the data itself but on the value added to this data.

   Moreover, the NWS should not add the FOS option to the existing University Top-Tier architecture. Although prices for the data may decrease with the FOS feed, NWS would effectively undercut and disturb the Top-Tier market that it created and relied upon to distribute the data. NWS essentially 'bites the hand that feeds it' if they institute the FOS option, and this will only bring harm to future cross-sector endeavors. Plus, the Top-Tier sites act as a valuable transitional organization between the government and the private sector, as they combine the credibility of government with the flexibility and scalability of a private organization. Some Level-II users commented that the increased level of service at the Top-Tier sites (compared to the NWS data feeds) is worth extra thousands of dollars per year.

5. The planned changes to the NWS network architecture should bring the reliability of Level-II data toward the mark needed for mission critical organizations. Not only do organizations use the Level-II data for eye-catching visualizations mostly seen on TV, but also for their internal forecasting needs which serve to alert clients to life-threatening situations. Thus, even though NWS has and will continue to make the Level-II feed more reliable, future technology transfer opportunities to NWS should occur with internal requirements matching those of the academic and private sector users. Since the mission of NWS is to save life and property and promote commerce, it should not be a distant stretch to argue for tougher internal goals to support the life saving and commerce building activities of the users of NWS-funded data.

5. MAJOR CONCLUSIONS

This final section will initially revisit the original questions posed in section 1.4.

Legal

- Does the Level-II program comply with applicable laws and directives concerning the dissemination of data collected with public funds? *Yes. Data is disseminated without restrictions, through the most technologically advanced channels, and at no more than the cost of dissemination to private sector users.*

- Are the providers of Level-II data complying with the rules of their signed Memorandum of Agreement (MOA)? *Yes. All data coming in to the Top-Tier site is available to users, and the fees seem reasonable and in the range of cost recovery for expenses.*

- Is the Level-II program transparent? *Not all the way through the program. The program is mostly transparent on the NWS side, although the NWS seems to frustrate users by making changes behind closed doors. Even though users appreciate the chance to offer feedback to the NWS, users are unclear about how the NWS uses this feedback in their decision* *processes. To users, it seems like their feedback goes into a black hole, which may or may not register the incoming information. The Top-Tier and user side of the Level-II program is not transparent at all, due to non-disclosure issues. While this is an expected piece of private industry, the reporting of aggregate statistics would shed light on the value of Level-II data and develop trust between the sectors by offering important but aggregate and anonymous data as a window into the private sector world.*

Technical

- Does the Level-II program use the most reliable and cost-effective networking architecture available? *Mostly. Communication failures between Unidata and NWS sometimes led to the use of old LDM software in the system. Also, some users argue that the NWS was slow to upgrade reliability-improving software, although the other side is that the ROC bas done a good job of maintaining a new system with a declining budget.*

- Is the Level-II program nimble enough to take advantage of advances in data processing and networking technology? *Yes. This is the true value of the Top-Tier sites. Since these organizations sell themselves on level of service to clients, they are in a position to rationalize new expenditures if they lead to increased service levels.*

Organizational

- Does the Level-II program satisfy its users? *Mostly. Users expressed displeasure with the unreliability of the data and lack of communications about planned changes to the system or radar outages. However, ALL USERS agreed that the Level-II data was a valuable part of their organization and despite the mentioned problems, they were generally happy to have the data. Because there is no quantitative systematic assessment of customer satisfaction, this answer is an inference based on interviews with users.*

- Are non-profit organizations the correct vehicle to distribute Level-II data, compared to a FOS option or the use of for-profit organizations with the NIDS program? *Yes. The government forbids private entities to have an exclusive franchise on the data (like NIDS) and the government cannot offer the level of service to match the Top-Tier providers. Top-Tier providers act as a communications filter between the users and the government and they provide a specialized and scalable service that the government cannot match. Even though the use of Top-Tier providers increases the costs to users, most said that this increased cost was minimal compared to the costs of communications to transfer the data, and that the increased costs are well worth the higher level of service offered by the Top-Tier providers.*

- Does the Level-II program provide a clear path of accountability? *Somewhat. Ultimately, users contact the Top-Tier site, and the Top-Tiers contact appropriate personnel at NWS. Initially, the Top-Tier sites were frustrated by the level of service offered by NWS, but as they proceeded up the learning curve and found the reliable personnel at NWS, the communications and accountability process became more streamlined and efficient.*

- Does the Level-II program provide clear, current, and complete communication between appropriate stakeholders? *There is room for improvement. Although a clear channel exists between the NWS, the Top-Tier providers, and the users, many Top-Tier providers and users do not feel that they have access to all the NWS communications concerning radar outages and planned system changes. The NWS currently uses mostly a pull communications strategy through webpage updates, but users would like more of a push strategy with email since many users forget to regularly check the updates on NWS webpages.*

Lastly, the following bullet points outline some general technology transfer lessons for the atmospheric sciences.

- The weather community must devise a system to ensure that opportunities for technology transfer are not accidental and ad-hoc. This entire Level-II story is the product of a few motivated researchers. The enormous value of real-time dissemination and archival of Level-II data should not be a story of timing and luck and the work of a few. Rather, this should be the story of a scientific community coming together and developing priorities for future technologies and collaboration.

- From the beginning, CRAFT involved all three sectors and had a goal toward the transfer of research into operations. This example of use-inspired basic research (Stokes 1997) yields a fantastic model for future projects.

- The value of Level-II radar is growing each year as users increase and the expertise of users improve. Rather than presenting anecdotes about the value of Level-II data, the community should collaborate on a set of metrics that will track the growth of the data and will tell the story of the value of Level-II. Although numbers are not perfect indicators of a program's value, they provide a baseline for year-after-year measure and are also helpful to quickly explain the success of a program to persons outside of the small Level-II community.

- There is still a great deal of animosity between the NWS and private sector weather providers. Although the interests of a bureaucracy and a for-profit company will never completely align, both entities seek greater support for the weather community and ultimately want to serve their customers to a high level of satisfaction. Rather than argue about who gets what piece of the pie, the community should, 1) develop a transparent process to make decisions about roles and responsibilities as outlined in Fair Weather and which is still a fictional reality that is not addressed in the latest version of NOAA's Partnership Policy (NWS 2005b), and 2) following the example of an agency like NASA, there is ample room for NWS and the private sector to make a case for new technologies and funding to enlarge the size of the pie. If NWS and private weather companies presented a clear story about the value of Level-II data and the need for better communications infrastructure at NWS to manage the network, each entity would get what they wanted – more reliable data and more financial support.

  Neither side – NWS or the private sector – has a clear and quantitatively supportable story, and until the numbers arrive to provide a foundation for disagreement, it is this author's opinion that the weather community will continue to suffer from a lack of direction.

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7. Appendix A: Definitions

Abilene
The Abilene network, a project of the University Corporation for Advanced Internet Development (UCAID) in collaboration with various corporate partners, exists to advance the mission and goals of Internet2.

CRAFT
Collaborative Radar Acquisition Field Test

ERC
Education and Research Consortium of the Western Carolinas

FOS
Family of Services

GigaPop
A consortium of universities and other research organizations within a given geographic area which have banded together to provide access to the Internet2 Abilene network. GigaPoP members share the costs of equipment space, circuits, personnel and other costs required to maintain the access to Abilene. NOAA and the NWS maintain memberships in several GigaPoPs in geographically diverse locations across the United States.

HQ
Headquarters

Internet1
The commodity internet or the mainstream internet.

Internet2
A consortium led by 202 universities working in partnership with government to develop and deploy advanced network applications and technologies, accelerating the creation of tomorrow's internet.

IRaDS
Integrated Radar Data Service

Level-II Radar Data
Level-II data is like a digital picture on your computer – using a program you can manipulate it (crop, darken, lighten, etc.) to suit your needs.

Level-II data provide the highest spatial and temporal resolution information. Commonly referred to as "base" data, NEXRAD Level-II data consist of reflectivity, radial velocity, and spectrum width (velocity variance) "moment" data generated by the radar processor. Each data set contains up to 14 tilts or elevation angles in conical planes of a spherical-polar coordinate system, with each tilt containing 360 radials of data. The azimuthal resolution is one degree for all quantities, and the radial resolution is 1 kilometer for reflectivity and 250 meters for both radial velocity and spectrum width.

Level-III Radar Data

Level-III data is like a picture on your wall – you can look at it, but you really cannot manipulate it (darken, lighten, etc) in any way to suit your needs.

Level-III data are essentially lower resolution pictures of the Level-II data. These pictures are a smaller file size than Level-II making them easier to share over a network with bandwidth constraints, but the pictures have little value compared to the Level-II data,which can be analyzed and manipulated in a wide manner to suit user needs.

NCDC
National Climatic Data Center

NEXRAD
NEXt Generation RADar. This name describes the entire network of WSR-88D radars, which was funded jointly by the Depts of Commerce, Defence, and Transportation.

NIDS
Nexrad Information Dissemination Service. During the 1990s, four private weather companies EACH had direct lines into all NEXRAD radars and centrally collected all the Level-III data. This data was then passed on to other users at reasonable fees, relying on competition between the four providers to keep prices low.

NOAA
National Oceanic and Atmospheric Administration, under the Department of Commerce

NOAAport
Dissemination of weather information centrally collected within NOAA over satellie communications.

NWS
National Weather Service, under NOAA

RPCCDS
Radar Products Central Collection/Distribution Service

TAMU
Texas A&M University

WFO
Weather Forecast Office.

WSR-88D
Weather Surveillance Radar 88 Dopper. These are the "new" radars installed after the modernization of the NWS and this name describes the radar itself.