RAVAR: A DECISION SUPPORT TOOL

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PURPOSE:

The purpose of this paper is to fulfill a contractual agreement, and to provide a document to WFDSS users to help understand all aspects of the RAVAR mapping and analysis process.

The contractual agreement is a Rocky Mountain Cooperative Ecosystems Study Unit. It is between the National Park Service, the College of Forestry and Conservation at the University of Montana, and the author of this document. This contract requires a final report that documents the major task for the duration of the research term. This document will fulfill that requirement.

RAVAR

INTRODUCTION:

The Rapid Assessment of Values at Risk (RAVAR), is a mapping and analysis process that assesses risk to values from active wildland fires to support strategic wildland fire management decisions. The RAVAR process analyzes GIS layers representing values at risk from an active fire, by using a fire behavior model, generally the Fire Spread Probability (FSPro) model. The RAVAR process developed out of a need to evaluate fire suppression expenses based on the cumulative value of the resources being protected. The goal was to develop a decision support tool that fire managers could use to decide on alternative strategies that would meet their objectives while reducing cost.

The RAVAR analysis process produces a report and a thematic map. The report is generally 3 to 8 pages in length depending on the amount of values at risk identified by the fire behavior model. It features tables displaying the Critical Infrastructure values at risk within the probability polygons of the FSPro analysis (See table 1). The report starts with a general description of the fire relying on several sources. It also contains brief descriptions of the FSPro model's predicted spread and potential limitations; as well as the model's predictions in relation to nearby communities, roadways, and critical infrastructure (See Appendix 2).

The thematic map displays the probability of the current fires path in relation to the values data (see figure 1, and appendix 1). The RAVAR group has had several seasons of developing this product and it has been vetted with feedback from fire managers who have used the product in the field. The RAVAR team provided maps and reports, generally less than two hours after a request, for the fire seasons of 2005 through 2010. In some of these seasons the team produced well over 100 RAVARs . It is currently beyond the development stage and being implemented by some Forest Service Regions. Examples of both the map and the report are offered as appendices to this document.

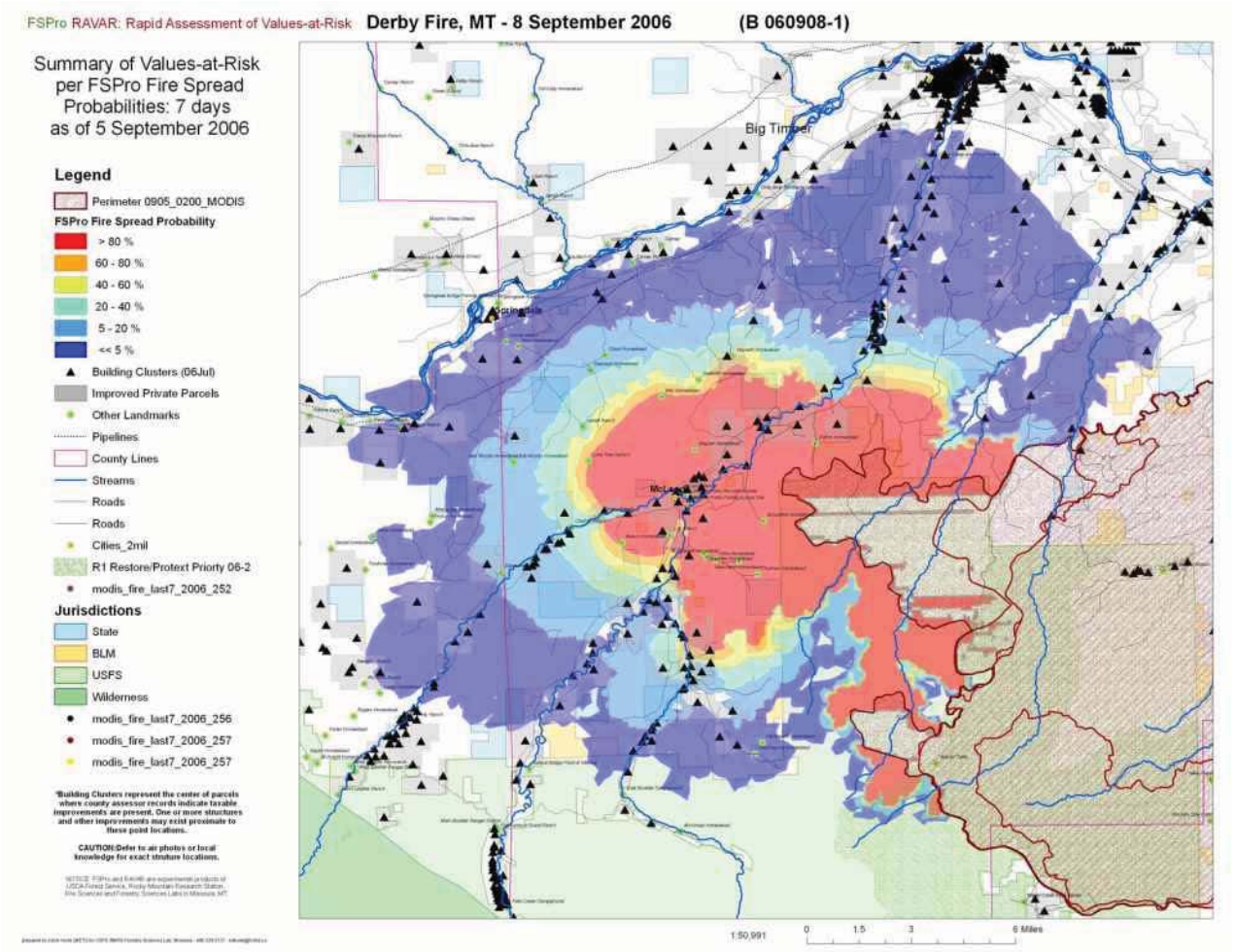

Figure 1: RAVAR from the Derby Fire 2006

Communication Towers		
FSPro Zone	In Zone	Cum.
> 80%	0	0
60 - 80 %	3	3
40 - 60 %	30	33
20 - 40 %	21	54
5 - 20 %	31	85
1 - 5 %	24	109

Table 1: Table from RAVAR report from the Cottonwood Fire, CA.

BACKGROUND:

RISK

The word "risk" is central to understanding this issue, it has taken on new meaning in the world of wildland fire. Risk incorporates the probable intensity and spread of a fire affecting a value change on a resource in terms of loss or benefit (Finney 2005). The last point of this statement is interesting; fire can theoretically be analyzed for its potential benefit to the ecosystem, future fire fighter safety, or economic savings.

THE BEGINNING

The rapid assessment of values at risk concept began roughly in the fall of 2004. Dave Calkin and Kevin Hyde, researchers at the USFS Rocky Mountain Research Station in Missoula MT, were looking at ways to compare the cost of suppressing a fire to the probable economic loss. The result was a published report "Break Even Point," (Calkin and Hyde, 2004). This report looked at two fires in Montana that were comparable in size and cost but not in proximity to values at risk (most importantly, habitable buildings). One fire was remote and the other was dangerously close to Missoula, the second largest community in Montana. Yet both fires received nearly equivalent suppression costs. This research led to the realization that the analysis process used for the report, could be used proactively by fire managers to make cost saving decisions on an active fire. The Rapid Assessment of Values at Risk (RAVAR) was born.

THE BUILDING OF BUILDING CLUSTER DATA

After the publication of the "Break Even Point" article the RAVAR team began exploring using this technique at a larger scale, primarily on Forest Service land and primarily in the 11 western states. They soon ran into a serious road block. The state, in which their research began, Montana, contained the only complete county cadastral data set in the nation. These data were housed at a state level and had consistent spatial and tabular data that could be used to identify if a plot of land contained a habitable structure. As research and production moved forward the assumption was made that if Montana-a state that is often underfunded and behind the times in technology- had these data sets available, then certainly the rest of the country must as well. Unfortunately, this assumption proved incorrect. The rest of the country had inconsistent cadastral data at the county level and often no effort to compile the data at the state level. As the building cluster layer is arguably the most important layer for active fire risk analysis, the RAVAR mapping and analysis process needed a complete national structure data set to offer useful analysis for wildfire.

Calkin and Hyde soon discovered that the Federal Geographic Data Committee's Cadastral Subcommittee (FGDCCS) was working on compiling cadastral data at a national extent (Hyde, 2009).

The Cadastral Subcommittee had been working with the data in hurricane recovery areas but they were experiencing limited county participation. Their efforts were directed towards data acquisition from affected counties after an incident. The wildland fire issue gave FGDCCS a reason to engage the fire prone western counties and encourage them to participate in proactively compiling a national data set that would be available for emergency response; rather than reactively compiling data after an incident for emergency recovery.

Meanwhile, in the 2006 fire season the RAVAR team acquired cadastral data for those counties outside of Montana on a fire by fire basis; and luckily in the areas where RAVARs were requested, most counties were able to provide useful spatial and tabular data that could be used to identify structures. This season had roughly 40 incidents in eight western states (FGDC 2007). In this early phase, counties were contacted when an incident began within their boundaries, which often led to a willing exchange of cadastral data from county cadastral GIS technician to the RAVAR GIS analyst (Hyde, 2009). The RAVAR team knew this wasn't sustainable, so following this season RMRS researchers and the FGDC Cadastral Subcommittee began to discuss ways to compile a complete western county building data set that would be available for rapid analysis.

Work began on collecting the cadastral data, in earnest, in the spring of 2007; by August of that year 251 of 414 western counties (not including Montana) had offered their cadastral data in some form (FGDCCS, 2008). Unfortunately this was not always in a usable format; the data often arrived lacking either geometry or the attributes necessary to identify which parcels contained habitable buildings. In that season, only 196 counties could be pre-staged and made available for use. See Figure 2 below.

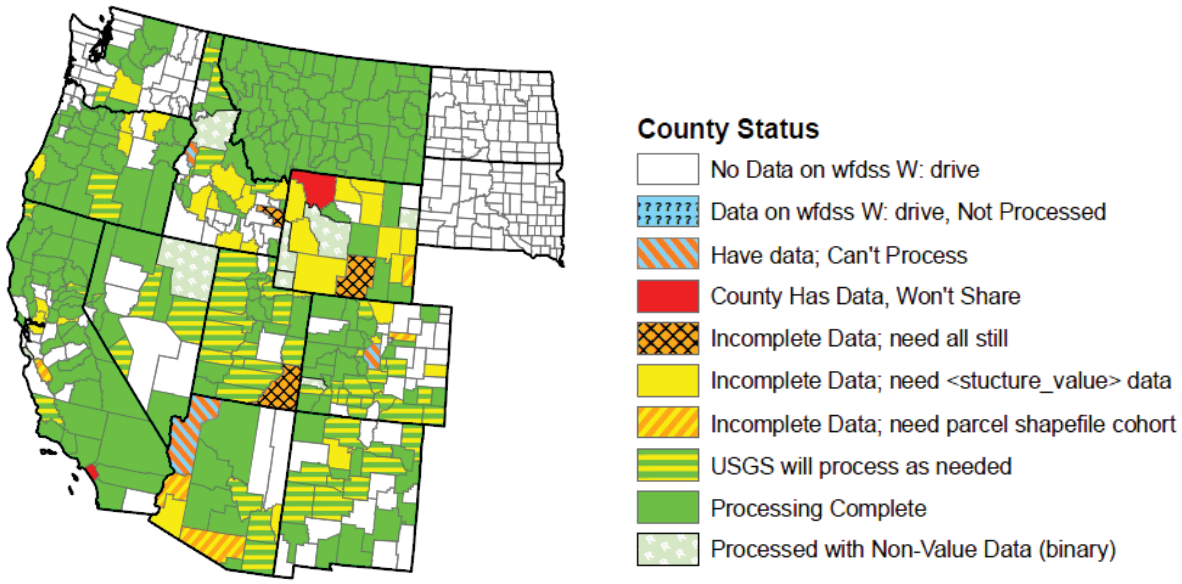

Figure 2: available county cadastral data in 2007 (map created by Jeff Kaiden for internal use at the RMRS. "W" drive refers to intra-RMRS storage space)

THE USGS AGREEMENT

Due to the lack of available structure data in some US counties, an alternative method to identifying potentially habitable buildings was developed. The RAVAR analysts began a relationship with The United States Geological Survey (USGS) in 2005 that formalized in 2006. This relationship allowed for the RAVAR analysts to call USGS with affected quadrangles and USGS would analyze aerial photographs to identify potentially habitable buildings. This obviously affected the response time and RAVAR analysts often prioritized quads that had the most probability of being affected in order to get the most important data in a timely fashion.

WHAT IS RAVAR

The RAVAR product is a report in the form of a Microsoft word document (sometimes exported as a PDF) and a map in the form of a PDF (see Figure 1 above or appendix 1). The map has been created using the ESRI ArcGIS software. This software is used with a specific RAVAR tool that was developed by the team. This tool analyzes the spatially enabled values at risk data that fall within the fire spread probability polygons created by the FSPro model. The findings of the analysis are displayed in tables featuring the amount or frequency of a value's occurrence per FSPro probability ring. See table 2 below.

The report also incorporates other sources of information such as the Delorme Gazetteer series, Google Earth images, and the ICS-209 report to ensure the consistency of data and to ensure that no crucial data has been overlooked. The final report is a mix of tables and descriptive statements that are meant to give a general picture of the fire's probable spread, the values at risk from the probable spread, and the fire's current location in relation to nearby communities and infrastrucutre (see appendix 2).

Jurisdiction	**USFS - Total**		**Private**	
FSPro Zone	In Zone	Cum.	In Zone	Cum.
> 80%	3,391	3,391	0	0
60 - 80 %	2,057	5,448	0	0
40 - 60 %	2,258	7,706	0	0
20 - 40 %	2,912	10,618	66	66
5 - 20 %	3,753	14,371	722	787
1 - 5 %	3,593	17,964	3,109	3,896

Table 2

COMPONENTS

The RAVAR product is created using a mix of GIS tools, models, and data. Some additional data is included and or referenced that is not spatial such as the National Wildfire Coordinating Group's ICS-209

report. Most GIS data comes from authoritative federal agencies, but in the case of the cadastral layer, counties provide information in response to a federal push from FGDCCS.

FSPRO

FSPro is a fire behavior model that produces rings of probability from the current fire perimeter or ignition point (WFDSS, 2006). It is based on the FARSITE model which considers surface fire spread, point of source fire acceleration, spotting, fuel moisture and crown fire (Finney 1998). This model is run over a raster image using fire related data with numerous iterations, each time varying fire related variables such as weather and fuel moisture. The image is then analyzed for the number of times each pixel burned in the various iterations. This number is divided by the total number of model iterations creating the expected probability for each pixel burning. Polygons are created using the pixels to identify categories of probability that buffer out from the current ignition point or fire perimeter (i.e. 100-80%, 80-60% 60-40%, 40-20%, 20-5%, 5-.2%, and <.2%). These pixels are then color coded for visual analysis.

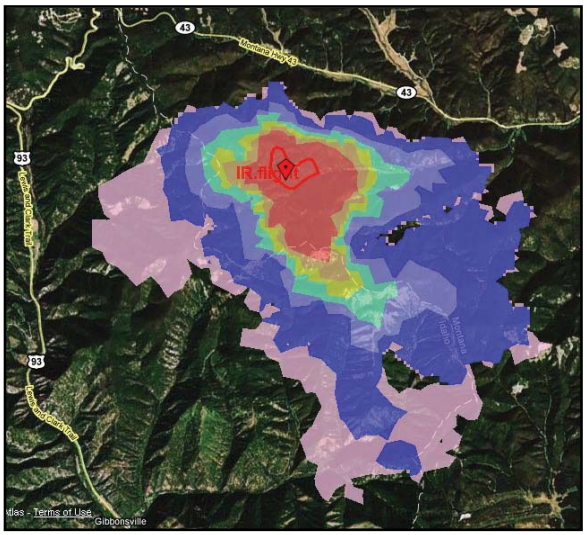

Figure 3: FSPro

FEDERAL BUILDINGS

In addition to county cadastral data, the Forest Service (FS), the Bureau of Land Management (BLM), and the National Park Service (NPS) have provided data on buildings that exist on their land and are maintained by them. These layers contain points representing potentially habitable buildings only, although data do exist for other structures.

These data sets are relatively recent additions to RAVAR (NPS 2009, BLM 2010, and FS 2010), but they are arguably as important as the county cadastral data in identifying valuable resources, especially those that may be habited by the most important value at risk from a fire, people. During the fire season, these federal structures may be occupied by non-federal persons, who may be unaware of current fire activity.

FS: Data for the FS came from the USDA FS INFRA data site. From this site, the data was queried at the regional level. This process yielded data in a tabular latitude longitude format which was used to create an ESRI shapefile. Then all regions were merged into a national layer. This layer became available in RAVAR in 2010.

The completeness of this layer is currently unknown, but it is known that several districts and a few complete forests have not submitted data to INFRA at this time (July, 2010). It is the responsibility of each forest to submit their data.

NPS: These data are collected by individual Park Units and have been compiled and processed at the NPS Resource Information Services Division. Further processing was performed at the Rocky Mountain Research Station in preparation for use in RAVAR and WFDSS.

Each park unit within the NPS is authorized to submit a collection of building GIS data that are used to establish points or polygons representing buildings derived from the digitizing of paper maps, using GPS devices to record point coordinates at the primary entrance, or other acceptable cartographic methods described in the Director's Order (DO 80, 2006, 4.1.1).

Tabular data came from Facilities Management Software Systems (FMSS). This software system was the answer to a federal mandate that specifically instructed NPS to create a maintenance management system. The documents created under this system contain detailed standardized information on structures. (nps.gov, 2009)

The FMSS tabular data and the spatial data for NPS buildings were joined and unnecessary attribute fields reduced by NPS analysts. The RMRS WFDSS/RAVAR GIS Specialist then modified the attribute table for the needs of WFDSS/RAVAR and eliminated those points lacking adequate attribution.

BLM: These data were provided by the BLM. Their currency and completeness are unknown.

CRITICAL INFRASTRUCTURE AND NATURAL CULTURAL RESOURCES:

Due to the potential wealth of information that could accompany an FSPro in a RAVAR product, a distinction was made about levels of data that could be grouped into separate maps, leaving maps less cluttered. There are then two maps that can be created that vary slightly in theme.

CI: The Critical Infrastructure (CI) map features things like structures, ownership, powerlines, communication towers, and water resources. These data sets are from federal sources that have been recognized as the authoritative agency on the particular data theme in question. These data sets are often at a national coarse scale.

> **Special Designated Areas**: A more specific example of a CI data set is the Special Designated Areas (SDA). This data depicts those federal lands that have a special designation (wilderness for example). A large part of this data was supplied by the Wilderness Institute, a private agency with the authority to compile spatial data for federal wilderness areas. Three other federal agencies provided additional data on designated areas such as Research and Natural Areas, the FS Inventoried Roadless Areas and the BLM Wilderness Study Areas. These areas are significant to fire managers as often fire fighting strategies and tactics change in these special areas.

The creation of these data sets relied on various sources that had varying degrees of currency, accuracy and national coverage. The position of RAVAR on data acquisition (and later of WFDSS) was to use the most authoritative source and assume that the accuracy, currency and coverage will suffice until a better alternative is provided.

NCR: On the other hand, the Natural and Cultural Resources (NCR) map features data themes such as critical habitat for threatened and endangered species, or other data that are important to local fire managers but not significant enough or extensive enough to constitute a national layer. The NCR data was compiled by the RAVAR team by contacting interested FS regions and asking them to provide spatial data sets that represented the needs of the lands under their jurisdiction.

ICS-209

The National Wildfire Coordinating Group provides a document called the ICS-209 which contains crucial information for a fire similar to the reports generated by RAVAR. This information is used by RAVAR analysts to check the RAVAR data for inconsistencies and lacking data.

MODIS:

These data points represent remotely sensed hot spots, generally caused by wildfire. Two satellites, Terra and Aqua, contain the Moderate Resolution Imaging Spectroradiometer (MODIS) equipment and work in tandem crossing the earth at crucial times of the day to Identify kilometer square pixels which are displaying heat at levels indicating a wildfire. These pixels are identified when they are displaying complete coverage of heat from all intensities of fire across the entire pixel; or a pixel may be identified when a small area within that pixel is experiencing a significant amount of heat such as that produced in a high intensity fire. Areas as small as $50m^2$ with extreme heat have been known to trigger a MODIS point for an entire kilometer pixel (MODIS web Page, 2010). Once a pixel is identified, a GIS point is placed at the center of the pixel representing what is assumed to be an active fire.

LANDFIRE

This dataset comes from a FS Fire Science Lab effort to create raster datasets for fire related applications. The themes are associated with land cover and geomorphic fire related topics. The RAVAR team uses the elevation data available to create a local hillshade for each RAVAR map.

CONCURRENTLY DEVELOPING FIRE DECSISION SUPPORT TECHNOLOGY

WFDSS

As the creators of RAVAR were introducing their concept of value at risk mapping to the field, a new decision support system was developing. The Wildland Fire Decision Support System (WFDSS) was created by the National Interagency Fire Center (NIFC). This decision support system was created to

assist in making fire management decisions as well as offering an online user friendly template for documenting those decisions. It was created in 2005 to take the place of Wildland Fire Situational Awareness (WFSA) the existing system used to document all fires that escape initial attack, escape a prescribed fire boundary, or escape an area designated for resource benefit. A short briefing paper published by the Forest Service describes how WFDSS will be in the experimental stages in 2005 and 2006 and ready for operation by 2008 (USDA FS, 2004) but statements on the WFDSS home page suggest that it was not "fully operational" until 2009 (WFDSS home page, 2010). The USFS made the use of WFDSS mandatory for all large fires in 2010.

Within this system both RAVAR and FSPro analysts found a home for their products. This was a mutually beneficial relationship in that both RAVAR and FSPro were important early components of WFDSS.

In addition to the full RAVAR analysis available through WFDSS, data sets compiled for RAVAR were used to support automated mapping, value at risk analysis, and other decision support tools in WFDSS. This system offers fire managers RAVAR style information in a less descriptive format.

Fire Management Unit (FMU)

The focus of WFDSS tends to deviate from RAVAR in that it incorporates fire planning objectives. Fire mangers are able to spatially display immediate planning decisions using tools such as Management Action Points (MAP). In addition, fire managers are able to incorporate long term local planning efforts in the form of Fire Management Units (FMU). The National Wildlfire Coordinating Group (NWCG) defines an FMU as:

> *" A land management area definable by objectives, management constraints, topographic features, access, values to be protected, political boundaries, fuel types, major fire regime groups, etc. that set it apart from the characteristics of an adjacent FMU. The FMU may have dominant management objectives and pre-selected strategies assigned to accomplish these objectives."* (http://www.nwcg.gov/pms/pubs/glossary/f.htm#Fire_Management)

FMU data were received from forest districts and compiled into a national layer. Currently, WFDSS has received data and made them available for roughly three quarters of the national forests (WFDSS on Frames, 2010). These data are displayed on a WFDSS map of the fire area. Also, key information from the FMUs are auto populated in the decision support system and the final WFDSS decision document so that the objectives identified by local researchers and managers are represented along with other relevant fire information.

CONCLUSION

The RAVAR process has matured and been vetted over 5 seasons. It is currently leaving its research and development home at the FS Rocky Mountain Research Station and being implemented by early adopters in interested FS regions. The hope is that these regions will tailor the process to their needs by incorporating data sets that reflect the local values in the context of the local fire behavior.

There has been a desire to expand the use of RAVAR to post-fire and fuel reduction applications, focusing on the benefit portion of the conventional definition of risk analysis. The RAVAR process has the potential to incorporate natural resource values that could benefit from active fire, especially when probability models that predict fire intensity are used.

The future applications of the RAVAR process is proving valuable as fire managers and policy makers are beginning to explore alternatives to fire suppression that could save money, reduce fire fighter exposure to potentially extreme fires, and in certain places, under certain conditions, allow fire to return to its natural role in the ecosystem.

The largest problem RAVAR and now WFDSS has to overcome is to find reliable data sources. FGDCCS, in its effort to compile a national buildings layer, has made the observation that the ideal situation would be for the states to take on the responsibility of data stewardship themselves (FGDCCS, September, 2007). RAVAR analysts often somewhat unwillingly took on the role of data stewards. This worked in the early phases of research and development, but as these tools, processes, and systems move forward and expectations for reliable data increase, there are complications that arise when national analysts, who are often far removed from the data source and have only a general knowledge of fire related data themes, must become stewards of local and/or specialized data. The ideal situation is to find data that has been created and made available by an authoritative source who is intimately involved in that data. The tools, processes, and systems described here are only as accurate as the data backing them.

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