

# RICH INTERACTIVE MAPPING EXPERIENCE THROUGH OPEN SOURCE FRAMEWORKS AND AJAX DATA VISUALIZATION TECHNIQUES

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## ABSTRACT:

Community indicator projects across America seek to understand and analyze the inter-relationships of multiple issues over a given geographic area, typically within an urban region or city. While maps can be well-suited to portraying urban development patterns, geographic information systems (GIS) typically are limited to displaying single or bivariate spatial relationships; additional spatial statistical tools are generally needed to analyze multivariate relationships. Online interactive GIS applications using a single map frame present an even more difficult challenge when attempting to visualize multiple variables at once, especially at multiple scales. New open source web frameworks and AJAX-style data display tools, though not designed specifically for GIS purposes, offer innovative ways of overcoming this challenge. A new online mapping application covering the Long Island region in New York provides an example of how to implement these frameworks and tools. It represents a compelling example of a production-level, customized application (rather than a mashup relying on Google-Yahoo-Microsoft basemaps) that nonetheless is replicable and extensible.

## 1. INTRODUCTION

This paper describes an application of new AJAX-style\* data visualization tools as part of an interactive mapping website in the New York metropolitan region. This example demonstrates the repurposing of tools such as dynamic transparencies to facilitate the effect of portraying spatial relationships of multiple data sets simultaneously for a given geographic area across a range of geographic scales.

The mapping website was developed for a regional community indicators project. Indicator projects in the United States compile and analyze a wide array of demographic and socioeconomic data to understand and monitor progress related to the vitality and resilience of urban regions. These projects seek to understand and analyze the inter-relationships among multiple issue domains to identify trends and map local and regional patterns (Kingsley, 1998). These domains can include housing, commercial development, population trends, transportation networks, environmental concerns, and more. Policies that facilitate housing growth, for example, can subsequently influence commercial development (and vice versa), which will help determine transportation access to and from workplaces, all of which will have environmental impacts.

While these policies can be evaluated at the regional and national scales, their impacts are felt at the local (Maantay J & Ziegler J, 2006) and even “hyperlocal” level (Kelly T, 2009). Housing might be built according to a suburban sprawl pattern, for example, or it could be concentrated in local downtown areas with commensurate commercial land use activities coupled with new public transit hubs and routes. Individuals living or working in or near these downtowns or along transit routes, as well as local planning agencies, advocacy groups, reporters and editors, and local elected officials want to

understand how these impacts will affect them. Maps are effective tools for visualizing these local impacts.

The *Long Island Index* is a community indicators project focused on the two suburban counties located just east of New York City (*Long Island Index*, 2009). A central goal of the *Index* is to make information about regional indicators easily and broadly accessible. The project also tries to localize the information as much as possible to make it especially relevant to people interested in their communities, as well as the island as a whole.

The original *Index* website ([www.longislandindex.org](http://www.longislandindex.org)) had provided “Community Profiles” consisting of static maps and tables highlighting Census data for each village, town, and city on Long Island. The *Index* had removed those profiles when its website was redesigned two years ago, but *Index* staff and its steering committee knew they needed to provide better access to this data – the *Index* regularly receives requests from public officials, the media, and community groups for information about what the *Index*’s indicators mean for local neighborhoods. The *Index* also knew that it needed an easier way of helping people make connections among multiple issues such as housing, transportation, and jobs.

The *Index* contracted with the Center for Urban Research’s Mapping Service at the Graduate Center of the City University of New York (CUNY) to apply GIS technology in an interactive, online environment to enable website visitors to mix and match data to suit their individual needs and reveal complex relationships in easily understood ways. *Index* staff wanted visualization tools that would allow users to quickly find a wealth of richly layered information without having to search multiple sites and resources.

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\* AJAX refers to “Asynchronous JavaScript and XML”. AJAX techniques are discussed more fully in Section 2.

## 2. RELATED WORK & ALTERNATIVE APPROACHES

The ability to overlay and simultaneously visualize multiple data sets, in particular those that represent administrative data aggregated across statistical boundaries such as Census areas or administrative districts, using GIS is not new. But only recently have web development tools made it feasible to do so in online mapping applications (Dykes, 2005).

Desktop GIS applications have used traditional cartographic techniques to accomplish this goal (Slocum, 2009) such as:

1. Multiple symbol types such as graduated symbols located at polygon centroids overlain on a choropleth map displaying color patterns across those same polygons.
2. Multivariate dot density maps, using different colored dots for each variable displayed within common spatial units.
3. Points and/or lines symbolized categorically overlain over a choropleth map.
4. Choropleth maps that combine texture (such as cross-hatching) with hue.
5. Transparency such as a semi-transparent hillshade choropleth draped over a digital elevation model.

Some of these approaches translate well in an online environment, such as overlaying line symbols on other map layers. But most of them either have not been implemented in online mapping applications or (in the case of dot density maps or choropleth+texture maps) lose their visual power when used in conjunction with satellite orthoimagery or color-shaded spatial units that are fine-grained such as tax parcels.

Another approach is a set of maps each covering the same geographic area, with each map displaying different data. This could be either a traditional atlas or the “small multiples” approach described by Tufte (1983). But interactive online maps generally use a single map frame. We wanted to follow the single frame approach for the Long Island Index, so this ruled out a traditional atlas or small multiples.

Geo-statistical packages are very good at displaying multivariate data using graphs and scatterplots (cf. GeoVISTA’s applications such as HealthVis; Edsall, 2001). But scatterplots do not display patterns in geographic space; they use Euclidian space to illustrate relationships. Also, these relationships are generally described for a large area (such as countywide or metropolitan statistics), rather than the spatial patterns in small areas such as within villages or even within Census block groups. The Long Island application needed to display these spatial relationships in very small areas as well as regionally.

Online GIS adds interactivity to traditional cartographic techniques, such as turning on/off different choropleth layers or clicking on the map to access each layer’s attributes. But until recently, online mapping did not offer much more functionality than that (Plewe, 2007). In 2005, web developers started to use a set of techniques referred to as “AJAX”, which was well-suited to enhanced interactivity for online mapping applications (Garrett, J.J., 2005). AJAX refers to Asynchronous JavaScript and XML. It was coined at that time to refer to a mix of different web development approaches that, when implemented together, enable web pages to behave more like desktop applications. For example, multiple components of single web pages designed using AJAX techniques can operate independently of each other and can each display data from

different sources. This makes the user experience less jarring, because the entire web page does not “refresh” or reload each time a user initiates an action (such as clicking a hyperlink), only that particular section of the page or layer on the page changes.

In the article that first described the AJAX approach, Google Maps was credited as one of the main examples of implementing AJAX beyond research projects (Garrett, J.J., 2005). The use of AJAX in Google Maps has since helped changed the way people expect to experience interactive mapping. The now-common technique of dragging a map and panning without first having to click on a special icon to enable panning is a result of AJAX, and clicking on the map and retrieving information about that specific location without the entire map reloading (or more severely, the entire web page reloading) is another.

At the same time, online mapping software has become easier to use, and consumer-oriented online mapping services such as Google Maps or Microsoft “Bing” Maps provide freely accessible application programming interfaces (APIs) to facilitate the integration of different data sets onto a common basemap (Plewe, 2007; Smith, 2008). One benefit to both of these approaches is that they are relatively easy to implement in a short amount of time.

However, they are not necessarily well-suited for projects such as the Long Island Index that require highly customized cartography and functionality (Smith, 2008). With the exception of the aerial orthoimagery, for example, the map layers for this project are all hosted at the CUNY Graduate Center. There was too much data to simply mash it up with a commercially available web map service, and we needed a greater degree of control over the cartography.

So-called first- and second-generation online mapping systems such as ArcIMS are GIS-centric but not as interactive as this project called for (Plewe, 2007). We wanted to develop the application using tools that would provide the kind of user experience that is now generally expected of online maps intended for a wide audience. For example, it would have been too onerous to require our users to first click a “hand” tool in order to pan around the map, or to click an “information” tool in order to access information from the map. We evaluated several open source alternatives to ESRI’s Web ADF and concluded that OpenLayers was best suited to our needs. (Going forward, ESRI’s new JavaScript and/or Flex APIs may be worth considering for new applications.)

The Mapping Service did explore open source options such as MapServer and GeoServer. But using those tools would have required learning new markup syntax for map styling and online cartography (such as GeoServer’s SLD files).

Other applications that are widely used such as Google Earth (<http://earth.google.com/>) and NASA’s World Wind system (<http://worldwind.arc.nasa.gov/>) also employ similar techniques, but these are desktop applications rather than websites.

By 2008, other online mapping applications had begun to integrate AJAX-style tools to facilitate the simultaneous display of multiple data layers. At the time, however, we identified only a few sites with a focus on community indicators that were employing tools to overlay multiple data layers within the same

map frame (such as PolicyMap at [www.policymap.com](http://www.policymap.com) and DataPlace at [www.dataplace.org](http://www.dataplace.org)). Even fewer sites enabled simultaneous visualization of multiple layers. MapTube was the main example we identified, employing a dynamic transparency “slider” for each layer displayed on the map ([www.maptube.org](http://www.maptube.org)).

Since deploying the *Long Island Index* application, other applications have been developed that employ a similar combination of technologies and techniques (cf. OpenGeo, 2009). Several open source projects now use Ext JS’s tools for online maps such as OpenGeo’s *GeoExt* framework ([www.geoext.org](http://www.geoext.org)), MapFish ([www.mapfish.org](http://www.mapfish.org)), and GeoCommons Maker! (<http://maker.geocommons.com/>).

### 3. APPLICATION OVERVIEW

The *Long Island Index* interactive mapping application is accessible at [www.longislandindexmaps.org](http://www.longislandindexmaps.org). It combines parcel-based land use data across the region, Census demographics, downtown surveys, aerial photos, and much more to create detailed neighborhood maps and give users a bird’s eye view on key housing, transportation, and development issues facing the region.

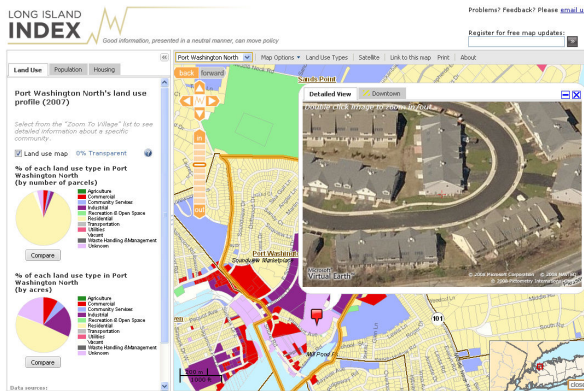


Figure 1. Screen shot of *Long Island Index* interactive map, zoomed in on the location of a new housing development, highlighting land use patterns and Microsoft’s “bird’s eye view” imagery integrated into the map frame

The mapping application features:

- Detailed property-level patterns of residential, commercial, industrial, and other land use types within each village and across Long Island. This data – provided under license by the Nassau and Suffolk planning departments – is not available in mapped format online anywhere else. It provides a rich picture of each of Long Island’s neighborhoods.
- Key population and housing characteristics from the 2000 decennial census plus statistics listed dynamically as users zoom in to each community. Census data is mapped by block group rather than the more common Census tracts because in many cases tracts were as big if not larger than villages. This meant that we could not display variation or patterns *within* many villages if we used tracts for the maps.
- Transportation and reference features such as aerial orthoimagery (provided by the New York State GIS Clearinghouse), bus and Long Island Rail Road routes,

boundaries of incorporated and unincorporated villages, special districts (such as fire, police, and sewer), and legislative districts.

- Dynamic bar charts comparing Census statistics from 1990 through 2007.
- Microsoft’s “bird’s eye view” oblique aerial imagery of any location on the map, embedded dynamically within the map frame. (The bird’s eye view photos are accessed via Microsoft’s “Bing” Maps API at [www.microsoft.com/maps/isdk/ajax/](http://www.microsoft.com/maps/isdk/ajax/).)

The map application supplements the *Long Island Index*’s annual reports and ongoing surveys. In conjunction with the January 2009 release of the *Long Island Index* 2009 indicators report, new data was added to the map including:

- Education statistics such as district size and statistics on affluence, finances and obstacles.
- Brownfield site information, showing the locations of 278 brownfield sites plus information for each on clean-up expenditures.
- Early childhood education program locations, plus child care capacity by school district.

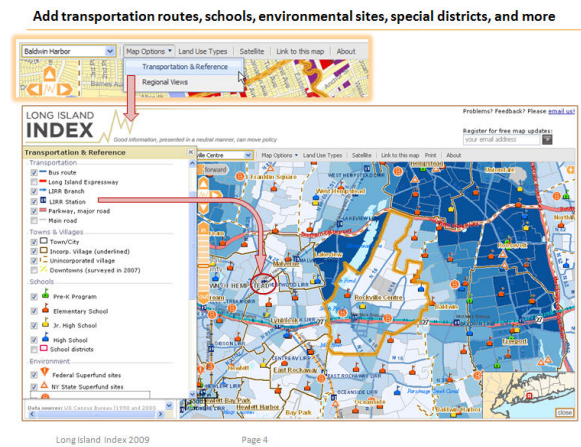


Figure 2. Local data sets such as pre-K, school, and brownfield locations and regional transit routes are featured

### 4. A HYBRID “GEO STACK”: OPEN SOURCE AND AJAX TOOLS ATOP PROPRIETARY BACKEND SYSTEMS

The development of open source software as well as standards-based application development have made it easier to integrate disparate technologies to create online mapping services. It is now feasible to use software for database management, cartographic rendering, map navigation tools, and a user interface framework all from different – including a mix of proprietary and open – sources. The Long Island application was developed using proprietary mapping and database technology on the back end, the open source map viewing library OpenLayers ([www.openlayers.org](http://www.openlayers.org)), and the JavaScript web framework Ext JS (<http://extjs.com/products/extjs/>). This combination of tools and frameworks enables the integration of sophisticated cartography, robust map services, and new visualization techniques.

The technology platforms include:

- ArcGIS Desktop from Environmental Systems Research Institute, Inc. (ESRI) to create map document (“MXD”) files for transportation and reference layers, land use maps, demographics and regional views and ArcSDE/SQL Server to manage the data sources (see [www.esri.com/products/index.html](http://www.esri.com/products/index.html) for details about ESRI software).
- ESRI’s ArcGIS Server to generate web map service (“WMS”) resources from the MXD files. The application also uses ArcGIS Server to generate cached tiles for the parcel-level land use map layer.
- OpenLayers consumes the WMS resources, manages and displays the map layers, and provides map navigation tools. The WMS resources consumed by OpenLayers include local resources created by the CUNY Mapping Service as well as remote resources such as the orthoimagery available from New York State’s GIS Clearinghouse; see [www.nysgis.state.ny.us/gateway/mg/webserv/](http://www.nysgis.state.ny.us/gateway/mg/webserv/).
- Dynamic data feeds are also provided via REST web services (such as village-specific statistics and comparison statistics).
- Ext JS provides the overall framework for the website itself and enables us to relatively easily integrate visualization and navigation tools such as dynamic transparencies, collapsible panels, and floating windows populated with dynamic data and charts.

The maps use ESRI’s platform on the back end because the CUNY Mapping Service has extensive experience using ESRI products to generate maps (online and offline). Though we have historically used ArcIMS (another ESRI product) to manage and serve online applications, the learning curve was minimal to install and use ArcGIS Server’s tools.

The Ext JS dynamic transparency tool is central to enabling the visual analysis of multiple layers at once (see <http://extjs.com/deploy/dev/examples/slider/slider.html> for a generic online demonstration of this tool). Although the Ext JS toolkit was not intended for GIS layers, we quickly realized it would meet this need.

The dynamic transparency operates on one map layer at a time, but it can be used to create the impression of visualizing a multivariate analysis. For example, a choropleth layer showing population density by Census block group is overlain on the land use layer that displays property-by-property land use patterns using a categorical color scheme, and the transparency of the choropleth is controlled by the map user from fully opaque (0% transparent) to fully invisible (100% transparent) by dragging a slider tool that automatically changes the transparency in 10% increments – see figure below.

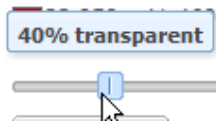


Figure 3. Screen shot of transparency slider tool

The AJAX approach controlled through Ext JS enables the choropleth Census map layer to change transparency without the rest of the page (or the other map layers) refreshing, so the transparency fades from one level to the next, becoming more or

less transparent in relation to the map layer beneath it dynamically.

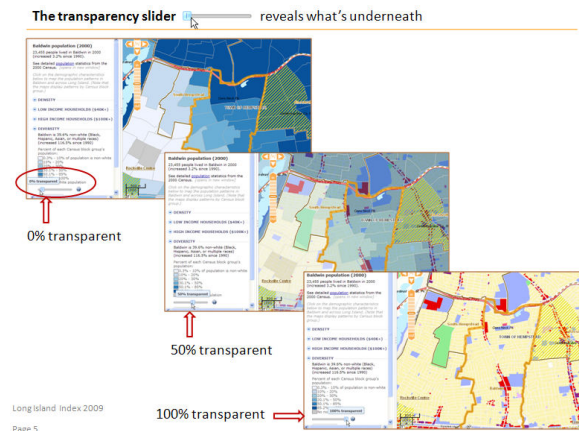


Figure 4. Excerpt from *Long Island Index* interactive map tutorial, explaining the use of the dynamic transparency tool

However, the transparency tool coupled with OpenLayers’ ability to instantly (and – through AJAX – without refreshing the rest of the web page or even the map itself) swap in and out different map layers creates the effect of viewing multiple map layers at once. One can set the transparency level of the land use layer at 20% with satellite imagery displayed beneath it, display a choropleth Census block group map of low income housing concentration at 40% transparent above the land use layer, and switch to a choropleth Census block group map showing patterns of multi-family housing at 100% opacity. Switching back and forth between the Census layers enables you to visualize the overlap between Census variables along with the land use patterns (three variables).

If you are zoomed in close enough on the map to discern building-level differences based on the satellite imagery (showing through the semi-transparent land use layer), you can use the same approach to also reveal how the actual land use patterns (a 4<sup>th</sup> variable) are related to the aggregated administrative data sets.

The Census Bureau cross-tabulates some variables such as poverty by income or race/ethnicity by sex and/or age. But Census variables such as the ones included in the Long Island Index application have not been cross-tabulated already, and none of them are cross-tabulated with variables such as land use (administered by a completely separate set of local government agencies) nor with transit routes or education data. Therefore, the Long Island application provides a unique way of visually analyzing the spatial relationships among these different socioeconomic characteristics.

Compare aerial photos with Census and land use patterns

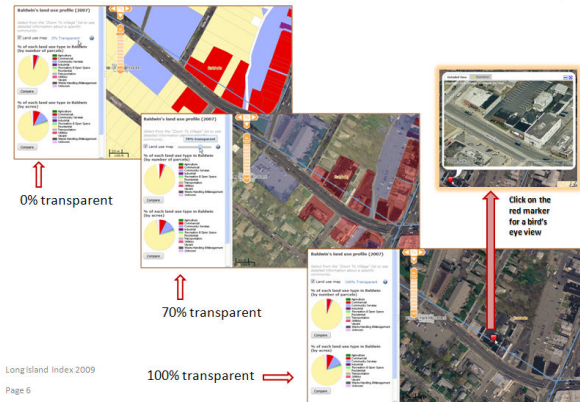


Figure 5. Excerpt from *Long Island Index* interactive map tutorial, highlighting how the dynamic transparency tool reveals aerial orthoimagery layered underneath a layer of tax parcel boundaries shaded categorically by land use

It is also important to consider the power of the transparency tool in the context of the transition from one transparency level to the next. Setting the transparency of a layer at a particular percentage using the transparency slider reveals the map patterns of the underlying layer. But watching the transition from 0% to 50% transparent, for example, makes the transparency “come alive”. As a recent web design handbook notes,

Things move smoothly in the real world. They do not “pop up”. Transitions smooth out the jarring world of the Web, making changes appear more natural. (Scott, 2009)

This also overcomes a potential concern with map transparencies. Once a map layer becomes partly transparent, the semi-transparent map colors no longer match the legend; they are influenced by the underlying map layer(s). We understood this concern when we developed the Long Island Index application, but hoped that application users would realize this limitation once they used the tool and modify their expectations accordingly (for example, another map developer using transparency controls notes that “The transparency control lets mapmakers decide what works and what doesn’t” – Axismaps.com, 2008). We have also created video tutorials and “frequently asked questions” (FAQ) web pages that address this issue.

Other AJAX tools included in the Ext JS framework that we applied to the Long Island Index application include:

- Interactive legend items that control the display of map elements without having to check a legend box and then separately click a “redraw map” button (cf. “smart legends” in Cron, 2008); and
- Data panels that operate independently of the map, but also control the map display. In particular, the Long Island Index includes an option to display “regional views” of pre-selected data elements. The Regional Views tool opens a panel that floats on the map (it can be moved or collapsed by the user). This panel includes a pull-down list that will change the map display by highlighting communities that meet certain criteria, such as all the villages across Long Island with more than 10% population growth from 1990 to 2000. Clicking a

community shown in the resulting data list will display that community’s detailed profile and highlight it on the map. Double-clicking on the community will cause the map to zoom to the community’s boundaries. Clicking the “zoom out” option in the panel will cause the map to zoom to the full extent of Long Island, showing the regional patterns of the selected data item.

Explore regional views of key demographic indicators

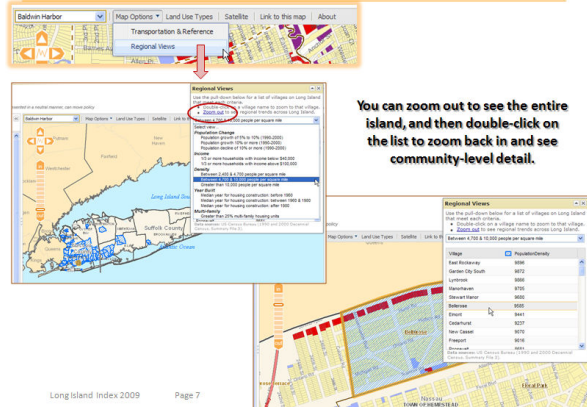


Figure 6. Excerpt from *Long Island Index* interactive map tutorial, demonstrating how AJAX-style drop down lists are linked with map navigation

### 5. REPLICABLE AND EXTENSIBLE

The *Long Island Index* interactive map application is replicable and extensible. With modest effort it can be modified to focus on other urban regions, and can be extended to include other visualization tools such dynamic charts and timeline controls.

Though it relies in part on proprietary software, other organizations without access to proprietary backend database and map development systems can substitute open source applications making the overall environment 100%-reliant on open source technologies.

Similarly, although the choice of variables and issue domains is pre-selected, with slight modification the platform can be designed to accommodate user-generated data, web services, and other dynamic content.

### 6. CONCLUSIONS

The interactive map was launched in December 2008. Since then several thousand individuals, local officials, community leaders, and industry representatives worldwide have used it. Access is free, and people can sign up for updates as the feature is expanded. Tutorials are available online for quick reference on how to navigate the maps and access the data.

The application is its own comprehensive but strategically-designed mashup, with a focused goal of illuminating regional and local planning issues across Long Island by visualizing statistics in new ways. It represents a novel implementation of multiple online mapping and web navigation technologies and techniques, customized specifically for displaying aggregated administrative data such as Census statistics at the block group level and education data at the school district level plus

transportation networks and site-specific environmental activities, all overlap spatially with parcel-level land use data and contemporary aerial imagery.

Lay audiences and industry experts alike have been impressed with the integration of AJAX tools in the Long Island application. The mapping feature already has been described as “an incredible resource” and a “data gold mine” by users who have ranged from high school students to industry experts to local newspapers to government officials across both counties as well as in New York City, San Francisco, Washington State, Oregon, Maryland, and Michigan. The maps have also attracted international attention. They have been accessed by mapping consultants and government representatives from Australia, France, Germany and Japan, as well as the geographic information officer for the United Nations.

As the *Index* continues to monitor and report on indicators of interest, the interactive map will be kept up to date as well. In addition to new data, the map will incorporate updates to data as public agencies and others make this information available. Updates from the Census Bureau will be incorporated, as well as annual land use updates from Nassau and Suffolk counties.

Above all, the *Index* wants to avoid adding data to the maps just for the sake of adding data. It is important that the maps continue to help reveal relationships of interest to the *Index*. For example, the wealth of education statistics compiled by local districts as mandated by state and federal agencies can be overwhelming. Simply tossing all that data into the mix would be counter-productive, helping to obscure rather than enlighten the public’s understanding of what lies at the heart of educational challenges and how to overcome them. The *Index* will strive to be strategic in how it further develops the maps, while also responding to feedback and requests from the public.

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