



Portfolio Case Study



Case Study Overview



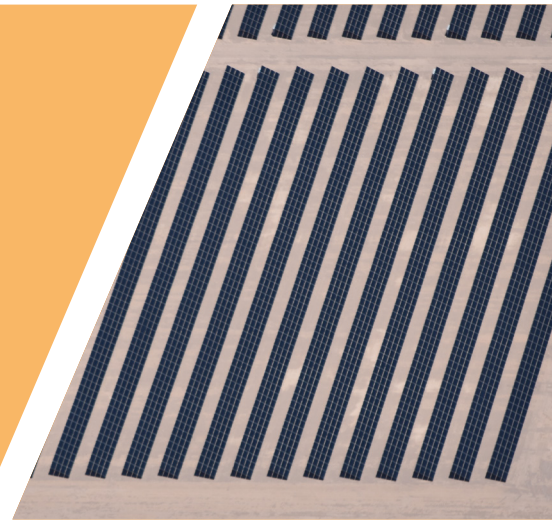
CLIENT INTRODUCTION

The following case study reports on heavily impacted sites owned and managed by a large, U.S.-based asset owner. The owner's total portfolio size spans over 410 MW of solar PV assets across the United States. The owner has multiple O&M vendors with teams stationed throughout the country. The PV systems within the portfolio range from 100 kW to 300+ MW, with a majority of their sites between 10-40 MWs.

CHALLENGES

Prior to leveraging Raptor Maps' turnkey services (aerial inspection + analytics), the asset owner was struggling with the following challenges:

- Increasing O&M costs with a larger and more distributed portfolio.
- Overcoming the challenge of efficiently scaling asset management operations.
- Standardizing their aerial thermal inspection data and reports from multiple O&M subcontractors using different methods and drone vendors.
- Insufficient data to begin prioritizing allocation of resources to address performance issues.



This case study highlights and breaks down five PV systems varying in size and location that utilized a mixture of Raptor Maps services. Some sites were inspected using Raptor Maps' turnkey services (aerial inspection+analytics and reports), while other sites were inspected by the client's subcontractor internal drone program. They collected the drone data themselves and then uploaded the data into the owner's Raptor Maps software account for the data analysis and report creation.

These sites were quickly and cost-effectively inspected, uncovering significant production and financial losses from anomalies and faults at the sub-module, module, and string levels. The asset owner was able to have each site inspected regardless of location, with the same standard operating procedures followed to provide standardized data across the portfolio. This enabled everyone involved in asset management and O&M to easily access the analytics and reports of each PV system. Raptor Maps services enabled the asset owner to effectively address the most impactful issues and increase portfolio performance.

KEY METRICS

Anomalies Identified



**6,241 Anomalies,
35,378 Modules
Affected**

Annual Power Loss



**11.61 MW_{dc}
or 3.91 %
Affected**

Annual Financial Loss



**\$517,684.73 Lost
if Anomalies
Unresolved**

Distributed Generation PV System

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SITE SPECIFICATIONS

Location: Minnesota, United States

Size: 5.9 MWdc

Service: Turnkey Service and Report

Inspection Level: Raptor Standard

Reason for Inspection: Annual Inspection

Anomalies Identified



**16 Anomalies,
2,853 Modules
Affected**

Power Loss



**391.4 kW,
6.71%
Affected**

Annual Financial Loss



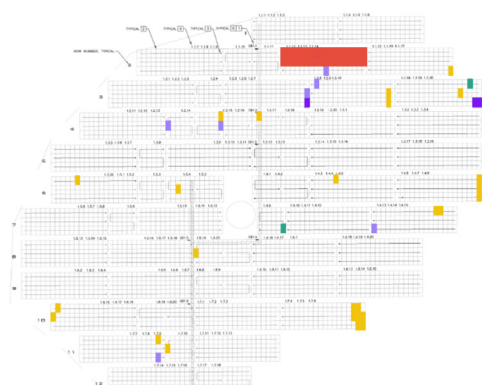
**\$17,450 Lost
if Anomalies
Unresolved**

SITE INTRODUCTION

The owner's 6 MW solar PV system was recently inspected as part of an annual preventative maintenance inspection using Raptor Maps turnkey services. A pilot was deployed within one week of the inspection request. The Raptor Standard level inspection took three hours of on-site piloting and provided the O&M team with sub-modular anomaly details through thermal and visual spectrum imagery. Raptor Standard level inspections can show anomalies from the inverter level down to the cell level. The inspection uncovered 490 system anomalies, categorized into 16 anomaly types, and amounting to 2,853 affected modules.

Some anomalies to note were instances of tree line shading, which affected over 2,200 modules, and combiner issues, affecting 324 modules. In addition, there were 3 strings and 68 individual diode faults discovered.

The owner's O&M subcontractor used the deliverables to identify the most impactful and easily remediated anomalies within the site. The deliverables enabled them to set up a plan to resolve all non-shading related anomalies within two weeks of the site inspection. The team started with the malfunctioning combiners to resume the 1.78% of lost production. The O&M team was already aware of the shading issues impacting the site, however, the shading impact had never been quantified. The O&M team used this new data to create a plan to resolve the onsite issues causing the shading and performance loss.



Anomaly	Anomalies (%)	Modules (%)	Est. Affected DC (%)	Est. Affected DC (%)	Est. Annual Impact (kWh) (%)	Est. Annual Impact (\$1) (%)
Cell Low	37	37	3.95 kW	0.07%	7201.95 kWh	\$180.05
Combiner	52	324	103.68 kW	1.78%	189216.00 kWh	\$4730.40
Cell Medium	12	12	1.28 kW	0.02%	2335.77 kWh	\$58.39
Cracking	12	12	3.84 kW	0.07%	7008.00 kWh	\$175.20
Diode	68	68	7.25 kW	0.12%	13236.01 kWh	\$330.90
Diode Multi	1	1	0.21 kW	0.00%	389.34 kWh	\$9.73
Shading	257	2297	244.99 kW	4.20%	44710.46 kWh	\$1117.62
String	3	54	17.28 kW	0.30%	31536.00 kWh	\$788.40
Totals	442	2805	382.48 kW	6.56%	698027.68 kWh	\$17450.69

This findings table has been filtered to show high priority issues only.

Distributed Generation PV System

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I SITE SPECIFICATIONS

Location: South Carolina, United States

Size: 13 MWdc

Service: Data Processing for the Client's Internal Drone Program

Inspection Level: Raptor Standard

Reason for Inspection: Annual Inspection

Anomalies Identified



**9 Anomalies,
2,400 Modules
Affected**

Power Loss



**326.8 kW,
2.66%
Affected**

Annual Financial Loss



**\$17,432 Lost
if Anomalies
Unresolved**

I SITE INTRODUCTION

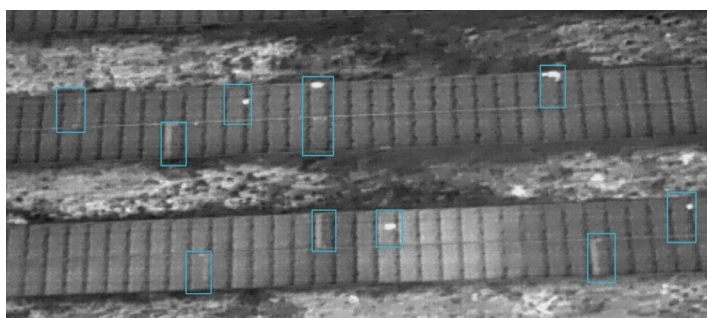
The O&M subcontractor responsible for operating and maintaining this solar PV system added an internal drone program to their inspection methods in 2019. Prior to using Raptor Maps' software solution, the team found the large amounts of data difficult to analyze and organize. Before the inspection, the plant was thought to be underperforming based on recent monitoring signals. Using Raptor Maps' flight guidelines, the O&M team successfully inspected the site with their drone and thermal imaging camera and uploaded the data for automated data-processing and received the inspection report. The inspection and reports uncovered 1,826 anomalies, falling into 9 categories, with 2,400 modules affected.

The report identified and located 10 malfunctioning strings, 379 diode faults, and over 400 cases of vegetation across the northwest side. The annual loss of production from the anomalies identified would total more than 600,000 kWh.

The O&M team used the reports and the visual spectrum images from the inspection to assess all 400 cases of vegetation and were able to instruct their vegetation management vendor to the exact locations for removal. The O&M manager also deployed field technicians to investigate the high number of modules affected by diode faults and remediate the 10 string anomalies impacting 0.5% of system performance. Along with this improvement, the O&M vendor utilized Raptor Maps' flight guidelines and data processing to perform preventative maintenance inspections regularly to maintain optimal site conditions.

Anomaly	Anomalies ⁽¹⁾	Modules ⁽²⁾	Est. Affected DC ⁽³⁾	Est. Affected DC ⁽⁴⁾	Est. Annual Impact (kWh) ⁽⁵⁾	Est. Annual Impact (\$) ⁽⁶⁾
Cell	457	457	4798 kW	0.39%	103157.43 kWh	\$2578.94
Cell Multi	586	586	92.30 kW	0.75%	198434.25 kWh	\$4960.86
Cracking	11	11	3.46 kW	0.03%	7449.75 kWh	\$186.24
Diode	379	379	39.79 kW	0.32%	85550.69 kWh	\$2138.77
Module	3	3	0.95 kW	0.01%	2031.75 kWh	\$50.79
Shadowing	26	350	36.75 kW	0.30%	79004.60 kWh	\$1975.11
String	10	190	59.85 kW	0.49%	128677.50 kWh	\$3216.94
Vegetation	412	412	43.26 kW	0.35%	92999.70 kWh	\$2324.99
Totals	1884	2388	324.33 kW	2.64%	697305.68 kWh	\$17432.64

This findings table has been filtered to show high priority issues only.



SITE SPECIFICATIONS

Location: Arizona, United States

Size: 79 MWdc

Service: Turnkey Service and Report

Inspection Level: Raptor Standard

Reason for Inspection: Annual Inspection

SITE INTRODUCTION

The O&M subcontractor managing this utility-scale PV system and other large solar assets in the region had a very tight timeline to complete their aerial inspections before the annual preventative maintenance visits. The subcontractor always completes the aerial inspections to use the reports in addressing issues during their site visits. Due to the time-sensitive situation, the O&M vendor required turnkey services and reporting to free up labor resources for other required activities. To complete the project for the client, Raptor Maps deployed two local and experienced drone pilots to the site within the same week the project was approved, and the inspection was completed that day. This site was found to be heavily impacted by over 13 types of PV system anomalies, with over 10,000 offline modules. The largest and most impactful issue identified was the 50 inverter faults, amounting to over 4% of annual production loss.

On top of the 50 inverter faults, the inspection identified 8 offline strings which were estimated to reduce production capacity by 84 kW. There were also 64 module level issues and 594 sub-module level anomalies. These reduced the PV system's production by 95 kW from the site's full operating capacity.

The O&M team knew that the site was facing inverter issues due to internal monitoring signals, but the number and location of them were unclear. Upon the report being delivered, the vendor prioritized their onsite task to resolve the various inverter faults causing the 4% daily performance loss. The report equipped them with the data needed to deploy the necessary number of technicians and resources to the affected areas of the PV system. In addition, they were able to deploy technicians to remediate the string and module faults on schedule.

Anomalies Identified



13 Anomalies,
10,967 Modules
Affected

Power Loss



3440 kW,
4.38%
Affected

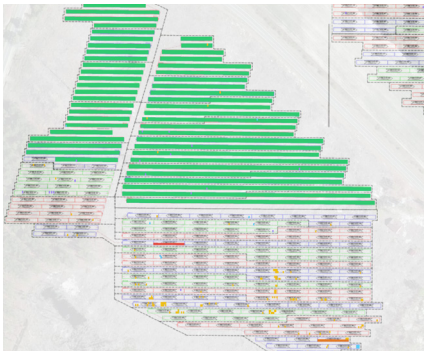
Annual Financial Loss



\$184,734 Lost
if Anomalies
Unresolved

Anomaly	Anomalies ⁽¹⁾	Modules ⁽²⁾	Est. Affected DC ⁽³⁾	Est. Affected DC ⁽⁴⁾	Est. Annual Impact (kWh) ⁽⁵⁾	Est. Annual Impact (\$) ⁽⁶⁾
Cell	284	284	30.76 kW	0.04%	66141.72 kWh	\$1653.54
Cell Multi	241	241	39.16 kW	0.05%	84199.38 kWh	\$2104.98
Cracking	3	3	0.98 kW	0.00%	2096.25 kWh	\$52.41
Diode	67	67	7.26 kW	0.01%	15603.86 kWh	\$390.10
Inverter	50	10034	3261.05 kW	4.16%	7011257.50 kWh	\$175281.44
Module	35	35	11.38 kW	0.01%	24456.25 kWh	\$611.41
Shadowing	14	14	1.52 kW	0.00%	3260.51 kWh	\$81.51
String	8	261	84.83 kW	0.11%	182373.75 kWh	\$4559.34
Totals	702	10939	3436.93 kW	4.37%	7389389.21 kWh	\$184734.73

This findings table has been filtered to show high priority issues only.



I SITE SPECIFICATIONS

Location: California, United States

Size: 199 MWdc

Service: Turnkey Service and Report

Inspection Level: Raptor Overview and Raptor Comprehensive

Inspection: Underperformance

Anomalies Identified



6 Anomalies,
19,013 Modules
Affected

Power Loss



7404 kW,
3.7%
Affected

Annual Financial Loss



\$296,196 Lost
if Anomalies
Unresolved

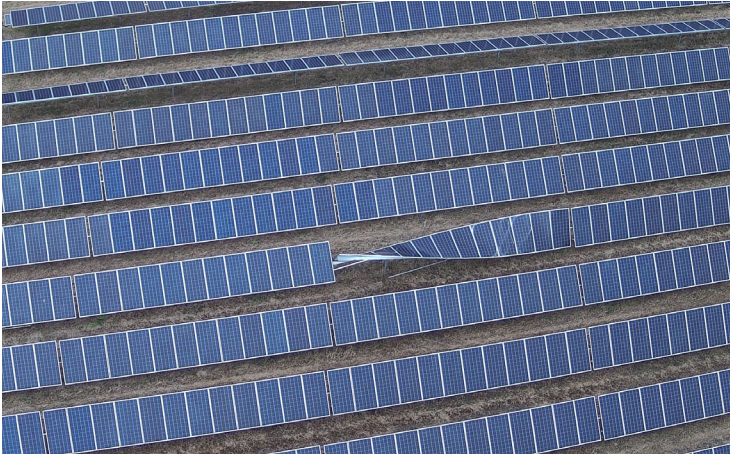
I SITE INTRODUCTION

This large utility-scale PV system’s O&M vendor was notified by internal monitoring systems that the site was significantly underperforming in various blocks. Due to the large size of the site, more than 1000 acres, and difficulty in locating the causes of underperformance with PV system monitoring tools, using field walks and IV-Curve tracing would have cost the team valuable time and labor resources.

The client consulted with Raptor Maps regarding what level of aerial inspection would be appropriate for this investigative inspection and chose a two-phase inspection. The first aerial PV inspection would be a high-level overview inspection to quickly identify major anomalies impacting performance and their locations as well as heavy concentrations of less impactful faults. After the completion of the first phase, the second deployment would be a Raptor Comprehensive level inspection, targeting heavily impacted areas of the site.

Raptor Maps deployed licensed and experienced drone pilots and both inspections took a total of 10 days. The inspection uncovered performance issues that fall into 6 categories, totaling 3,114 anomalies. There were almost 20,000 impacted modules which amounted to over 7 MW of production lost.

Anomaly	Anomalies ^{*(1)}	Modules ^{*(2)}	Est. Affected DC ^{*(3)}	Est. Affected DC ^{*(4)}	Est. Annual Impact (kWh) ^{*(5)}	Est. Annual Impact (\$) ^{*(6)}
Cracking	2	2	0.85 kW	0.00%	1700.00 kWh	\$34.00
Hot Spot Multi	17	17	4.82 kW	0.00%	9633.38 kWh	\$192.67
Missing	21	496	210.80 kW	0.11%	421600.00 kWh	\$8432.00
Module	24	24	10.20 kW	0.01%	20400.00 kWh	\$408.00
String	2727	16362	6953.85 kW	3.48%	13907700.00 kWh	\$278154.00
Tracker	323	2112	224.40 kW	0.11%	448800.00 kWh	\$8976.00
Totals	3114	19013	7404.92 kW	3.71%	14809833.38 kWh	\$296196.67



Large Utility PV System cont.

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| SITE SPECIFICATIONS

Location: California, United States

Size: 199 MWdc

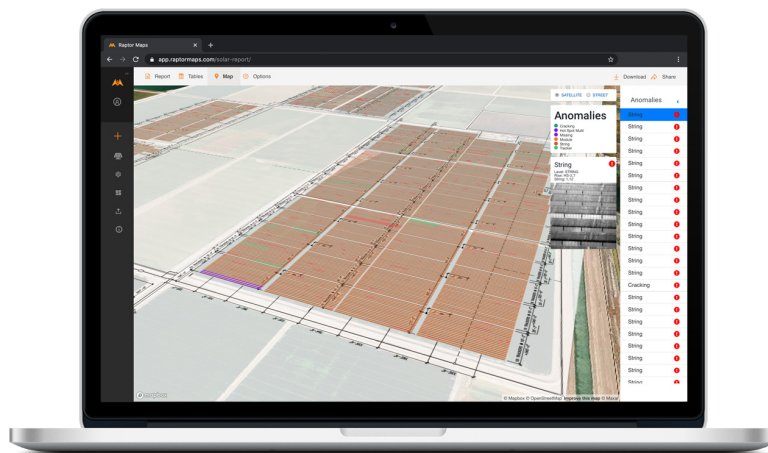
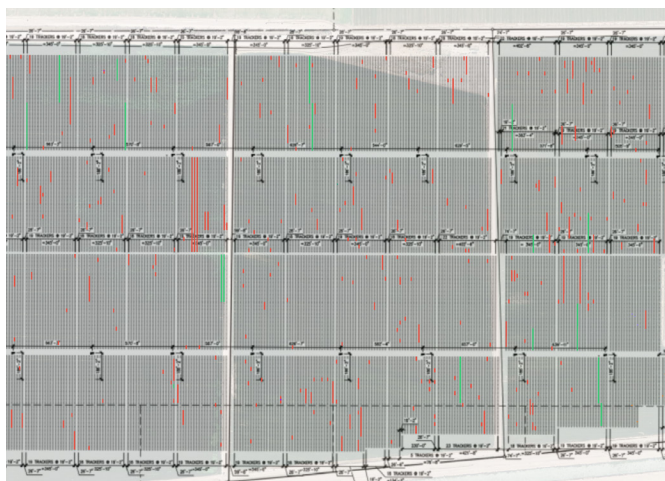
Service: Turnkey Service and Report

Inspection Level: Raptor Overview and
Raptor Comprehensive

Inspection: Underperformance



The two major anomalies uncovered were string and tracker issues. The string faults were the most impactful, with more than 2,700 individual string anomalies, impacting 3.48% of the total site production and costing almost \$300,000 in annual PV system revenue*. On top of that, \$8,000 of annual revenue was lost due to tracker faults.



The O&M team utilized the interactive map available in the Raptor Maps platform and also printed out the PDF and Excel spreadsheet reports to create a resolution plan. Due to the large size of the site and scattered anomaly locations, the site manager was able to deploy their team to the required areas, prioritizing mobilization based on performance impairment. The team was able to resolve all major issues within a few weeks and return the site to optimum production levels five times faster than if they had used older and more labor-intensive methods of field investigation.

*The estimated annual fiscal impact is the estimated annual impact in kilowatt-hours multiplied by the amount (\$) per kilowatt-hour i.e. power purchase agreement (PPA) rate.

SITE SPECIFICATIONS

Location: New Jersey, United States

Size: 0.86 MWdc

Service: Turnkey Service and Report

Inspection Level: Raptor Comprehensive

Reason for Inspection: Annual Inspection included in the O&M's scope of work

SITE INTRODUCTION

The rooftop solar PV system was inspected through Raptor Maps' turnkey services. Raptor Maps deployed a licensed drone pilot to the site within two days of the inspection request and executed contract. The Raptor Comprehensive level of inspection took one hour to perform, including pre-flight setup, flight time, and equipment breakdown. The Raptor Comprehensive inspection provided the O&M vendor with 3cm/px GSD radiometric infrared JPEG data and 1cm/px GSD high-definition visual spectrum JPEG data, exact temperature deltas for each module, complying with IEC TS 62446-3 regulations for aerial thermography. This inspection uncovered the following anomalies: 4 hot cells, 6 cracked modules, and 1 inverter offline.

The four-cell anomalies amounted to an annual loss of around 600 kWh. These anomalies were categorized as a low priority due to the trivial production and financial loss estimates.

The O&M team focused their resources on fixing the offline inverter and cracked modules, which would result in over 80,000 kWh of lost production, and \$1,800 in lost revenue annually. Utilizing the interactive map in Raptor Maps software, which shows the locations of each anomaly over satellite imagery and PV system as-built, the O&M manager overseeing the site sent the exact number of repairs and supplies needed to remediate the site's issues. Due to this site being on a rooftop, performing the inspection via aerial thermography prevented any inspection related injuries and minimized the amount of time any deployed technicians were on the roof.

Anomalies Identified



**11 Anomalies,
136 Modules
Affected**

Power Loss



**45.33 kW,
5.27%
Affected**

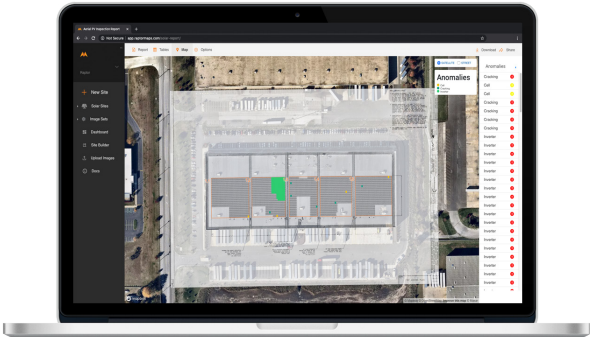
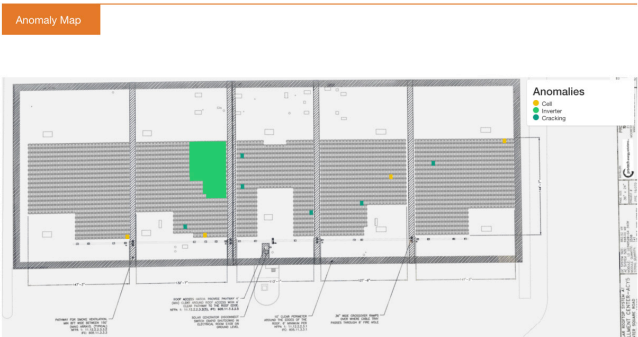
Annual Financial Loss



**\$1,870 Lost
if Anomalies
Unresolved**

Anomaly	Anomalies *(1)	Modules *(2)	Est. Affected DC *(3)	Est. Affected DC *(4)	Est. Annual Impact (kWh) *(5)	Est. Annual Impact (\$) *(6)
Cell	4	4	0.45 kW	0.05%	747.93 kWh	\$18.70
Cracking	6	6	2.04 kW	0.24%	3366.00 kWh	\$84.15
Inverter	1	126	42.84 kW	4.98%	70686.00 kWh	\$1767.15
Totals	11	136	45.33 kW	5.27%	74799.93 kWh	\$1870.00

Anomaly Map



Conclusion



The client used Raptor Maps solutions to support their O&M teams in early 2019. Within nine months, over 340 MW of sites were flown, analyzed, and reported on through a combination of turnkey services and in-house drone operations, using Raptor Maps software for processing and reports.

Raptor Maps enabled the asset owner to overcome their challenges related to increasing O&M costs, unstandardized aerial inspection methods, data and reports, and inefficient asset management operations. With Raptor Maps' turnkey services and software for in-house drone operations, the asset owner:

- **Decreased O&M costs while growing their portfolio in volume and distribution by providing countrywide turnkey services and data analytics quickly and affordably.**
- **Efficiently scaled asset management's ability to oversee their growing portfolio with more granular data on each PV system, down to the sub-module level.**
- **Standardized their data collection process for sites inspected by Raptor Maps' turnkey services and those inspected by their O&M subcontractor's internal drone program.**
- **Enabled more data-driven decision making to help the team identify where to focus O&M resources to address major performance issues first and capture a strong ROI.**

| CONTACT US

For more information on the case study, the services used, or to learn more about Raptor Maps contact us at:

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