Project Close-Out Report

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Abstract

This document presents the final project report for P05.05.02. It presents a management summary of the key results from the project. It describes the deliverables produced by the project and the relationship to other SESAR projects. It also provides a "lessons learned" review of the successes and issues encountered by the project.

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This deliverable consists of SJU foreground.

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Publishable summary

Project 05.05.02 is focussed on the near-term use of flight planning data, prior to the advent of standards and infrastructure to support full trajectory exchange between aircraft and ATC systems. As such the concept has the potential to be one of the early wins from the SESAR research phase. Sharing airline operational control (AOC) data with ATC could provide quick improvement to ground trajectory prediction, with limited investment.

NATS, EUROCONTROL and eight participating airlines (Air France, British Airways, FlyBe, Netjets, Novair, Swissair, United Airline and Virgin) have contributed to SESAR P5.5.2 to perform a series of validation exercises. The objectives of these exercises were to:

1. Assess ground ATC trajectory prediction (TP) improvements using AOC data (provided prior to departure) instead of assumed information (e.g. BADA default tables);
2. Evaluate the impact of these TP improvements on ATC medium term conflict detection tools, in terms of safety and efficiency;
3. Provide a Cost-Benefit Analysis for ANSPs and Airspace Users.

In order to allow early implementation, only AOC data requiring minor modifications to ATC and AOC ground systems were considered. AOC data were assumed to be provided through point-to-point communications between FOC and ATC, rather than ATFN, or SWIM.

The evaluations were made on NATS operational system (iFACTS) using mass and speed from AOC flight planning systems. Because the information comes from flight planning systems, the need for airborne systems to be upgraded is avoided.

AOC data from the participating airlines (e.g. take-off mass and speed from flight planning systems) and ATC systems information (e.g. ATCO input, meteorological information) were collected from operational flights over two days, in UK airspace.

This allowed comparison of the two following scenarios by replaying the traffic situation on iFACTS:

- Baseline scenario with ground trajectory predictions made using aircraft mass and speed assumptions (pre-determined information)

vs.

- "AOC data" scenarios using AOC mass and/or speed data, known by flight planning systems before take-off.

It was anticipated that TP accuracy improvements would result in reduced false and missed conflicts alerts rates from tools like MTCD (medium term conflict detection). This has been tested using both air traffic controllers' subjective assessment and quantitative modelling.

Furthermore, two costs-benefits analysis workshops have been facilitated by SESAR WP16 to assess ANSP and Airspace users costs and benefits using the EMOSIA (European Model for Strategic ATM Investment Analysis) approach.

Objective 1: ATC trajectory prediction (TP) accuracy improvement

The analysis of ground TP altitude & time errors showed that using both AOC mass and speed information together minimizes altitude errors during the climb phase. The most frequent altitude error rate value reduced from about 350 ft/min in the baseline scenario to about 100 ft/min in "AOC mass & speed" scenario.

It has been validated that AOC data usage can be added in a current/near-term TP algorithm (iFACTS) with limited development effort, and can provide improved ground trajectory prediction.

Objective 2: Operational benefits: Safety & Efficiency

Modelling work provided a comparison of false and missed conflict alerts rates at ECAC level (e.g. baseline vs. AOC data scenarios false conflict alert rates for cruise/climb conflicts.)

Both, missed and false conflicts alert rates due to TP errors reduced thanks to AOC data usage in TP calculations. These improvements were maximum (about a 10% reduction) for conflicts involving climbing aircraft using both mass and speed AOC data.

If only one AOC data item is used, it is the mass information which provides the maximum benefit, also during the climb phase. Benefits in cruise are of smaller magnitude while benefits in descent were not statistically significant due to a reduced data set sample.

Subjective assessment validated that controllers preferred the MTCD output when iFACTS was connected to the "AOC" ground TP.

Objective 3: ANSP and Airspace Users Costs/Benefits Analysis (CBA)

The following two benefits for ANSPs have been acknowledged by the CBA working group:

1. Safety benefit due to a reduction in the number of missed conflicts,
2. Controller workload reduction thanks to the reduction of nuisance alerts.

Cost for software development was estimated at 1 FTE per industry ground supplier plus ANSPs who develop their own ground system. Other costs such as software maintenance or training were considered to be small enough to be covered by current planned budgets.

The communications costs are linked to the assumption that AOC data might be provided through point-to-point communications between FOC and ATC, rather than ATFN, or SWIM. This has been assumed to allow for early implementation.

Benefits for the airspace users have been assessed in terms of fuel economy linked to increased continuous climbs. At ECAC scale, assuming 100% flights are sharing AOC data, airspace users net present value (benefit) is about 5 Millions € and benefit-to-cost ratio is estimated between 3.5 and 10. The probability that this project would lose money is only 10%.

It should be noted that more benefits can be expected (e.g. descent phase and arrival management, flow management) and it should be expected that infrastructure costs would be shared with other projects.

Conclusions

Most significant improvements were observed on trajectory predictions in the climb phase. Sharing AOC data should allow more continuous climbs (Airspace user fuel economy) and fewer false and missed conflicts alerts (safety benefit).

Moreover, a high participation rate is not necessary to obtain significant benefits. A 10% participation rate would be sufficient to balance costs and benefits.

1 Introduction

1.1 Purpose of the document

The purpose of this document is to:

- Summarise the results and conclusions of project 05.05.02 – the publishable summary;

- Describe the contribution to the development of new Standards and Norms Proposals through 05.05.02;

- Describe the contributions made to the roadmap for deployment activities through 05.05.02;

- Explain the progress made towards the execution of the ATM Master Plan through 05.05.02;

- Provide an overview of the final achievement of the deliverables from P.05.0502 and provide a management summary of the outcome versus the original plan.;

- Provide for each member (NATS and Eurocontrol), a Project Costs Breakdown Form of the total Eligible Costs incurred by the Member during the Project, including interest accrued on the Pre-Financing payments and any other Revenue related to the Project. **Note this information is sent directly to the SJU by members and is not directly included in this report**.

- Analyse the lessons learnt at project level.

1.2 Intended readership

This section lists specific projects or groups that may have an interest in this report. In general the reader is assumed to be familiar with the ATM process, in particular in the TMA environment and the associated terminology.

SESAR P05.05.01 & P04.05: These projects address the definition of the business and mission trajectory – the Trajectory Management Framework. Trajectory Prediction is a key function with Trajectory Management, which is particularly relevant in the near-term during which very few aircraft will be equipped to provide downlinked trajectory data. Hence the 5.5.2 results have been shared with and both projects and contribute to the TMF OFA.

SESAR P05.02: 05.02 is responsible for the overall TMA concept and the results of 5.5.2 have been delivered to and reviewed by 05.02.

SESAR P05.06.02: The fast time simulation of the effects of TP accuracy on tactical de-confliction of CCDs may be of interest to improve the availability of efficient vertical profiles.

SESAR P05.07.02: The concepts being developed by many primary projects are dependent on the use of accurate trajectory information. The 5.5.2 concept for improving TP therefore offers a potential benefit to these projects. P05.07.02 is an example of a primary project which has a dependency on TP.

SESAR WP03: While this project has performed its own validation, the techniques and strategy may be used in future integrated validation exercises which may include the concept of using additional planning information to enhance ground based TP capability.

SESAR P 07.06.02: WP7 and P7.6.2 specifically have related requirements to 05.05.02 for the sharing of AOC data. P05.05.02 deliverables have been reviewed by P07.06.02 and the requirements are embedded in WP7 documents – see P07.06.02 OSED.

SESAR WP 08: P05.05.02 is an early step towards the SWIM concept for sharing of information and in the long term it should be expected that the underlying communications mechanism for sharing AOC data is SWIM based. P05.05.02 deliverables have been shared with and reviewed by WP8.

SESAR WP 10.02: This SWP is responsible for developing TM prototypes, including development of the TP capability. P5.5.2 deliverables have been reviewed by P10.2.1.

SESAR WP 11: It is important the flight data sharing developments proposed by P05.05.02 are consistent with the FOC work of WP11. Coordination with WP11 has been achieved through WP7 - P05.05.02 requirements are embedded in WP7 deliverables.

SESAR WP 16: The validation results described in the D04 deliverable from this project were achieved with support from WP16, in terms of guiding the methodology and directly supporting workshops.

Airspace Users: Airspace Users have been closely involved with this project from the start, and have made a significant contribution to the successful completion of the project, both in providing data to make the analysis possible and through inputs to workshops and review of documents.

Other Industry stakeholders: As a near-term improvement of the current ATM system the results of this project have potential interest and application for both ATM industry companies and ATM providers. Significant interest was received when interim results were presented to the ATM Global Conference in March 2012 and several requests have already been received for copies of the final technical deliverable (D04). Making this and other deliverables publicly available may facilitate uptake and implementation of the concept proposed.

1.3 Inputs from other projects

Trajectory Prediction is a core enabling function for many advanced ATC tools such as Conflict Detection and Resolution tools, AMAN tools, complexity tools and others. As such the performance of the Trajectory Predictor has a direct effect on the performance of the overall ATC tool.

The development of Trajectory Prediction was sponsored prior to SESAR through a number of European and US-based programmes and the reports from these were available. These studies included:

- **FASTI**: A Eurocontrol programme which sponsored research into advanced ATC tools and included several TP development studies. Operational Requirements and the results of these previous TP studies were available to 05.05.02.

- **FAA/Eurocontrol AP16**: AP16 was a group within the FAA/Eurocontrol coordination framework dedicated to the development of Trajectory Prediction capabilities. TP Functional Requirements from AP16 exist and were available to P05.05.02.

- **BADA**: A core function of any TP is the aircraft performance model (APM). The standard APM for use in many TPs is the Eurocontrol BADA model. The iFACTS TP which was enhanced through this project is based on BADA and it is reasonable to expect that the results are applicable to other BADA based TPs.

- **EP3**: The EP3 project which preceded SESAR studied the use of Air-Derived Data to improve TP performance. This showed that improvements in TP performance are possible through the use of Air-Derived Data. However the use of Air-Derived Data requires changes to airborne infrastructure. Use of the AOC data studied by 05.05.02 is not dependent on any changes to aircraft equipment and hence could be implemented sooner and with relatively small costs.

- **ADAPT study**: This was an early start SESAR project (Ref. T06 22316TC) which estimated the benefits possible from improved TP performance.

1.4 Glossary of terms

Term	Definition
ADD	Aircraft Derived Data
Aircraft Intent	Aircraft Intent is the aircraft operations plan that defines precisely HOW the aircraft intends to meet the constraints and preferences defined in the Flight Intent. Aircraft Intent constitutes an unambiguous description of the trajectory, essential to provide interoperability among the stakeholders.
AMAN	Arrival Manager: An ATM tool that determines the optimal arrival sequence times at the aerodrome and/or possibly at other common route fixes (e.g. IAF)
ANSP	Air Navigation Service Provider
AO	Aircraft Operator
AOC	Airline Operational Control
AP16	EUROCONTROL-FAA Action Plan 16
ATCO	Air Traffic Controller
AU	Airspace User
B/C	Benefit to Cost Ratio
BADA	Base of Aircraft Data – EUROCONTROL
BT	The Business Trajectory (BT) is the representation of an airspace user's intention with respect to a given flight, guaranteeing the best outcome for this flight (as seen from the airspace user's perspective), respecting momentary and permanent constraints. The term Business Trajectory describes a concept of operation, rather than a set of data.
CBA	Cost Benefit Analysis
DAP	Downlinked Airborne Parameter
EMOSIA	European Models for ATM Strategic Investment Analysis
ETA	Estimated Time of Arrival

Term	Definition
FASTI	First ATC System Tools Implementation
FDP	Flight Data Processing
Flight Intent	The Flight Intent is an element of the Flight Object that describes the constraints and preferences that are applicable to the flight. It describes what needs to be achieved.
Flight Object (FO)	The Flight Object (FO) represents the system instance view of a particular flight. It is the flight object that is shared among the stakeholders
FOC	Flight Operations Centre
i4D	Initial 4D (from B04.02)
iFACTS	Interim Future Area Control Tools Set – NATS
INTEROP	Interoperability Requirements
MT	The military Mission Trajectory (MT) is similar, but more complex than a civil Business Trajectory. A military mission trajectory will usually consist of a transit to and from an airspace reservation with mission specific dimensions and characteristics. Outside and inside of an airspace reservation a single trajectory could be used by multiple aircraft.
OFA	Operational Focus Areas
OSED	Operational Service and Environment Definition
RBT	The Reference Business Trajectory refers to the Business Trajectory during the execution phase of the flight. It is the Business Trajectory which the airspace user agrees to fly and the Air Navigation Service Providers (ANSP) and Airports agree to facilitate (subject to separation provision).
RMT	Reference Mission Trajectory
SWIM	System Wide Information Management
TBO	Trajectory Based Operations refers to the use of 4D trajectories as the basis for planning and executing all flight operations supported by the air navigation service provider.
TMA	Terminal Manoeuvring Area. Within scope of SESAR, the TMA is defined as the airspace containing that portion of the flight between take-off and Top of Climb and between Top of Descent and landing.
TP	Trajectory Predictor. From B04.02: Trajectory prediction is the process that estimates a future trajectory of an aircraft through computation. This is performed by a Trajectory Predictor.
TPRT	Trajectory Predictor Research Tool (NATS)
TOM	Take-Off Mass

Term	Definition
TS	Technical Specification
WOC	Wing Operations Centre

2 Project contributions

2.1 Progress made toward the ATM Master Plan

Project 5.5.2 is an early win project which has addressed the Time-Based Operations phase of the ATM Master Plan (Step 1).

An explicit objective of the ATM Master Plan for Trajectory Management development during Step 1 is "*More accurate Trajectory Prediction and Trajectory Optimisation*". P5.5.2 has focussed on the development of the Trajectory Prediction performance through one specific mechanism – the use of flight planning data provided by AOCs. The enabling role of TP within many advanced ATC tools means that the results of this project have potential to be a key-building block for the Time-Based Operations phase of SESAR.

Also from the ATM Master Plan, stated performance objectives for Step 1 are:

- To improve the ATM capacity by a more reliable planning based upon the sharing of an accurate flight profile.
- To improve flight efficiency by a better anticipation and management of the various ATM system constraints allowing more optimized flight trajectories and profiles.

The results of P5.5.2 are applicable to both these objectives.

The operational concept and changes which have been addressed by P5.5.2 are relevant to the following Operational Improvements. It should be noted that the scope of 5.5.2 supports these OIs but it does not address the entire scope of these OIs.

CM-0104: Automated Controller Support for Trajectory Management

CM-0204: Automated Support for Near Term Conflict Detection & Resolution and Trajectory Conformance Monitoring

IS-0301: Interoperability between AOC and ATM Systems

The validation activities have assessed the benefits which can be obtained through implementing the P5.52 concept with regard to the Key Performance Areas of **Efficiency** and **Safety**. The benefits achievable would be realised by both airspace users and ANSPs. These benefits have been assessed to E-OCVM V3 level.

The conclusions show that the most significant improvements were observed on trajectory predictions in the climb phase. Sharing AOC data should allow more continuous climbs (Airspace user fuel economy) and fewer false and missed conflicts alerts (safety benefit). Moreover, a high participation rate is not necessary to obtain significant benefits. The results of the Cost-Benefit analysis suggest that a 10% participation rate would be sufficient to balance costs and benefits.

2.2 Contributions to the roadmap for deployment activities

Project 05.05.02 has been planned and agreed with specific consideration to ensuring that concept is feasible in the near-term. It is a Step 1 project and the technical enablers required to implement the project have been deliberately kept as simple as possible.

Some specific factors behind the concept which make it feasible in the near-term are:

- No changes to aircraft equipment fit are required. The data studied would be provided by AOCs. So very expensive and time-consuming aircraft modification costs are avoided.

- The concept builds on existing Trajectory Prediction capabilities: There are several Trajectory Predictors in operational use now in Europe. This concept has demonstrated that it should be possible to improved the performance of these systems but it does not require that the existing systems need to be completely replaced. Hence the investment costs and timescales can be reduced.

- The concept does not require 100% participation by airspace users in order to deliver benefits. The results of the Cost-Benefit Analysis suggest a participation rate as low as 10% could provide a net benefit.

- The ground communications infrastructure needed to share the data between AOCs and ANSPs already exists though it requires some amendments to software – amendments to protocols for sharing flight plan information. These requirements are agreed with WP7.

So the conclusion of this study is that an early implementation of this project is possible, in line with Deployment Roadmap and the business case indicates a strong likelihood of an overall net benefit, with benefits derived by both airspace users and ANSPs.

Looking ahead, an investment decision to implement this concept would also need to consider the other concurrent investments in the candidate FDP system as these would have an impact on the sharing of costs. For example to implement this in NATS iFACTS system it would be necessary to align the timing of the TP upgrade for this concept with other iFACTS and related FDP upgrades. Specific investment decisions will require consideration of some local factors.

Several expressions of interest in the results of the project have been received, both from within the SESAR programme and from external organisations. Although the validation and reporting activity of this project is considered complete, it is recommended that a mechanism is found to allow continued support to related areas of the SESAR programme (WPs 7 and 11) and wider dissemination.

2.3 Contribution to standardization

As an operational project this project has focussed on developing and validating the high-level operational requirements for the use of Flight Planning data to improve Trajectory Prediction. The technical formats for exchange of the data were not a direct deliverable from the project. The final set of operational requirements is documented in D04.

However in the course of developing the concept synergies have been identified with the needs for exchange of AOC data identified by WP7. The P5.5.2 requirements for exchange of AOC data have been included in CFMU data exchange requirements being prototyped by P7.6.2. (see P07.06.02 OSED).

The use of the AOC data within a Trajectory Predictor requires modifications to the Trajectory Predictor. For BADA based TPs the use of mass information would not require substantial algorithm changes and the modifications can be left to local implementation decisions.

3 Project lessons learnt

What worked well?
Clear Focus: This project has had a clearly defined focus from the initiation phase. With a focus on early implementation there were fewer assumptions and enabling factors involved which allowed the concept and validation objectives to be clearly defined, and hence clear validation exercises to be established.
Support of the Airspace Users: This project has benefited from strong support and direct assistance from Airspace Users throughout. Airspace Users have actively supported the project through provision of data for validation purposes and through subjective review of the concept. The project obtained support from Airspace Users both through the SJU Airspace User participation process and directly from some Airspace Users.
Proven Validation Techniques: The incremental nature of the change considered by P5.5.2 allowed the project to make use of existing TP validation techniques, with some adaptation and development.
Project Structure and Partners: The relatively small-scale of the project (only two partners) allowed the project to create a work breakdown structure which was based primarily on the experience and capabilities of the partners, and has minimised the administration effort associated with multi-partner projects.
What should be improved?
Scope and role of TP within SESAR structures: The role of Trajectory Prediction as an enabling function which supports many ATM tools and concepts means that it does not fit naturally with the overall SESAR decomposition of projects into operational projects and systems projects with their associated deliverable types. TP development is neither a purely system matter nor an end-user operational concept. This has created some difficulties both in establishing the appropriate relationships with other SESAR projects, and in trying to present the project results using the standard SESAR deliverable templates.
Dissemination of results: Since the project has completed the agreed validation activities and delivered positive findings, it seems clear that there will be continued interest in the project results beyond the formal closure of the project. There is on-going related activity with the SESAR programme (WP7 and WP11) and expressions of interest have been received from organisations outside the SESAR programme. It is recommended that a mechanism be established to allow support to these on-going activities. (**Recommendation**)
Other Trajectory Prediction development: Project 05.05.02 is the only SESAR project which has addressed the development of Trajectory Prediction functionality, and it should be recognised that P05.05.02 has had a tightly defined scope in this respect. There are other areas of TP development needed to support the wider SESAR concept (e.g. use of PRNAV, use of time-based clearances) which will need enhanced TP support and which are not currently being addressed. There are many primary projects enabled by TP – e.g. 5.7.2, 5.7.3 which have a need for TP to be developed. It is recommended that consideration be given to how this TP development is sponsored. (**Recommendation**)

Table 1 - Project lessons learnt

4 Project achievements

4.1 Project deliverables

Del. code	Del.Name	Description	Assessment Decision	Explanations
D01	Concept for the use of AOC data to improve Trajectory Prediction	D01details the concept of improving ground based trajectory prediction systems by using additional information generated in the flight planning process. Based on prior research on this concept, an in-depth analysis of ground based TP systems and, a questionnaire on the flight planning process to various airspace users, a list of the most promising parameters is established. The concept is subsequently applied to a number of example scenarios which are used to identify possible cost-benefit mechanisms. This document concludes the V1 phase of the project.	No reservation (P)	Note: this document is not formally an OSED but describes a concept at the level of the Trajectory Predictor. TP is an enabling function for many operational tools and concepts.
D02	Validation Plan for Enhanced TP using AOC data	D02 provides the plan for the V2 and V3 validation of the concept of using AOC data. This document describes the validation activities which were planned: two analyses using actual operational data to determine the effects on TP accuracy, two to translate the change in accuracy in example operational scenarios and an integrated simulation to gather expert judgement on the effects on an example ATC tool implementation of TP. The final two exercises applied the concept to a present-day operational system and evaluate the effects on the ATC tool itself.	No reservation (P)	

D03	Validation Results for Enhanced TP using AOC data	The results for the V2 validation of the concept are presented. Validation was performed in 5 exercises: two analyses using actual operational data to determine the effects on TP accuracy, two to translate the change in accuracy in example operational scenarios and an integrated simulation to gather expert judgement on the effects on an example ATC tool implementation of TP. The final exercise applied the concept to a present-day operational system and evaluated the effects on the ATC tool itself.	No reservation	
D04	Final project report on the concept and benefits for improving TP using AOC data	D04 provides the final set of Operational Requirements for use of Airline Operational Control (AOC) data in the computation of ground-based trajectory prediction. The validation was performed using actual operational scenarios and operational data in a near- operational system and evaluates the effects on the ATC tool itself by gathering expert judgement on the effects on an example ATC tool implementation of TP. The document reports the Cost Benefit Analysis (CBA) for the discussed concept identifying the costs and benefits associated with airlines providing their actual take-off aircraft mass and speed profile flight planning data to Air Navigation Service Providers (ANSP). The document also describes the proposed Safety Acceptance Criteria for the concept.	to be assessed	This document brings together the key results of the projects: • Validation Exercise results • CBA results • Safety Acceptance Criteria • Final Operational Requirements As such it is wider in scope than the VALR template.
D06	Preliminary Operational Requirements for use of AOC data	D06 provides the preliminary set of Operational Requirements for use of Airline Operational Control (AOC) data in TP.	No reservation	Originally assessed with “major reservations”. Following review the comments were addressed and D06 re-submitted.
D07	Project Close-Out Report	This document.	to be assessed	

Table 2 - List of Project Deliverables

4.2 Other Successes

As part of the Cost-Benefit analysis the project conducted two workshops with stakeholders, in particular with airspace users. These workshops were successful in meeting their validation objectives and also in the wider aim of generating Airspace User interest and support for the P05.05.02 concept. Airspace Users attending the workshop expressed strong support for the concept an in interest in how it will be taken forward to implementation.

[redacted] attended the ATC Global conference in March 2012 to present the concept and initial results from P0.05.02, as part of the SJU workshop on 4D Trajectory Management. The presentation was successful in generating significant interest in the project.

5 Total Eligible Costs

This section is based on the Project Costs Breakdown Forms of the eligible costs incurred by project Members during the project and these will be sent to the SJU separately by each member. The Project Manager should not complete this section.

6 References

[1] **SESAR B.04.02**: SESAR Trajectory Management Document, Edition 00.02.90, Sep 2010

[2] **SESAR 05.05.02**: PIR Part 1, Edition 00.04.00, May 2010

[3] **SESAR 05.05.02:** Preliminary Operational Requirements for use of AOC data, 05.05.02-D06, 00.01.00, 17 Dec 2010

[4] **SESAR 05.05.02:** Concept for use of AOC data to improve Trajectory Prediction, 05.05.02-D01, 00.01.01, 03 December 2010

[5] **SESAR 05.05.02**: Validation Plan for Enhanced TP using AOC data, 05.05.02-D02, 00.01.01 21 January 2011

[6] **SESAR 05.05.02**: Validation Results for Enhanced TP using AOC data, 05.05.02-D03, 00.01.01, 21 December 2011

[7] **SESAR 05.05.02**: Final project report on the concept and benefits for improving TP using AOC data, 05.05.02-D04, 00.01.00, 18 May 2012

[8] **SESAR 05.05.02**: Presentation to ATC Global, March 2012, The Use of Flight Planning Data to improve ATC Trajectory Prediction

[9] **SESAR 07.06.02:** OSED v0.7

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