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April 25th 2018

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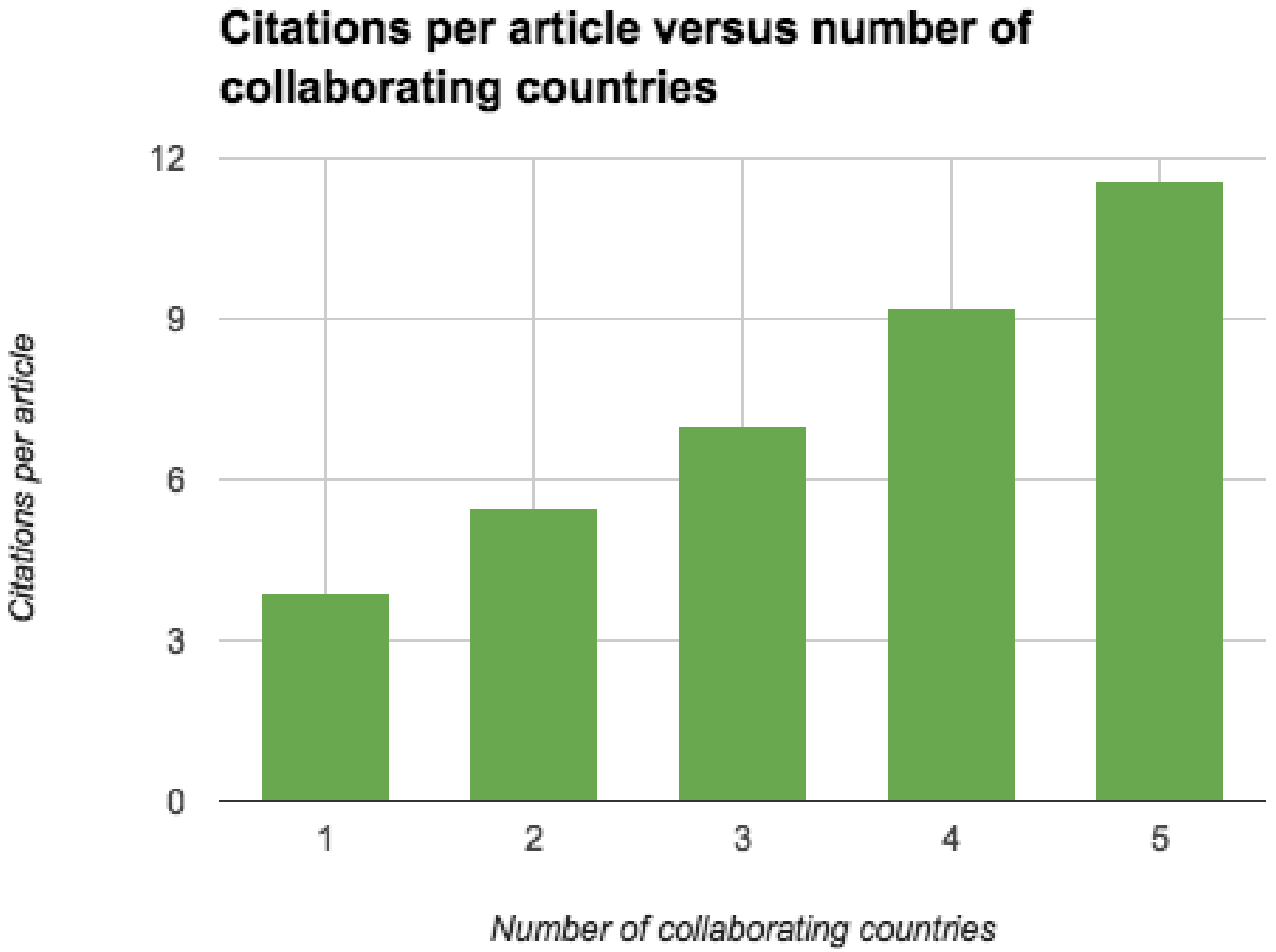

Source: Knowledge, networks and nations. Global scientific collaboration in the 21st century - The Royal Society - 2011

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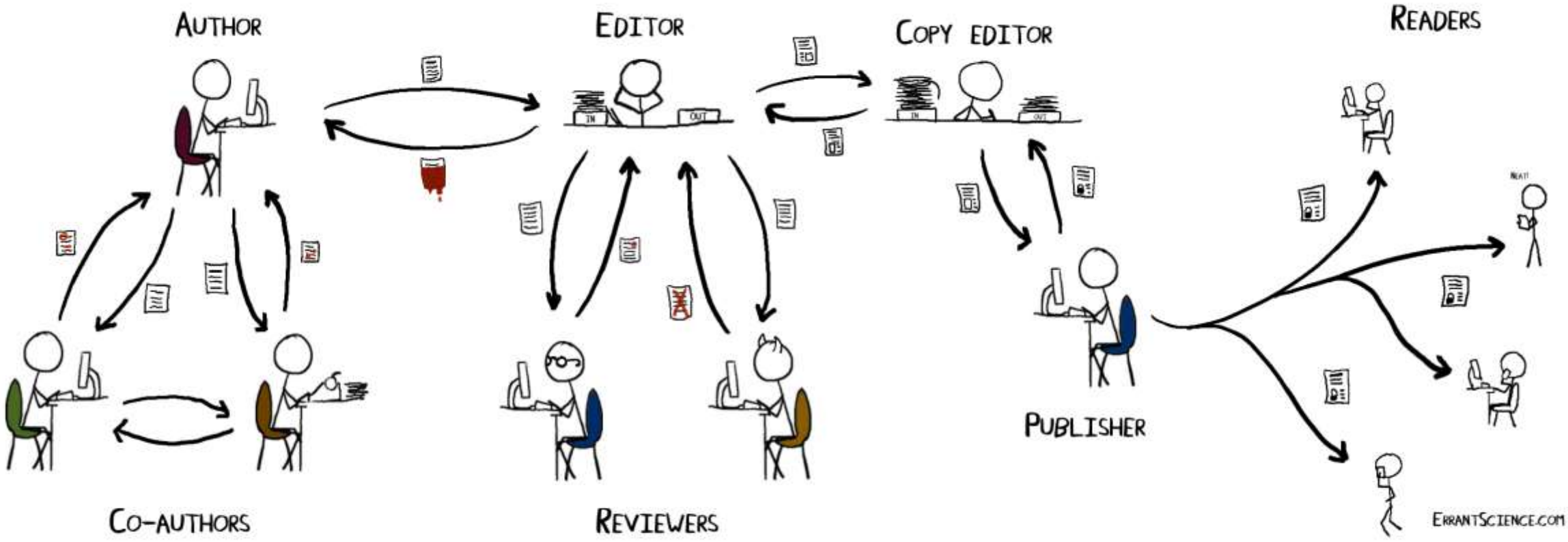

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Modeling of Trap Induced Dispersion of Large Signal Dynamic Characteristics of GaN HEMTs

O. Jardel1, S. Laurent2, T. Reveyrand2, R. Quere2, P. Nakkala2, A. Martin2

S. Piotrowicz1, M. Campovecchio2, S.L. Delage1

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Abstract

We propose here a non-linear GaN HEMT model for CAD including a trapping effects description consistent with both small-signal and large-signal operating modes. It takes into account the dynamics of the traps and then allows to accurately model the modulated large signal characteristics that are encountered in telecommunication and radar signals. This model is elaborated through low-frequency S-parameter measurements complementary to more classical pulsed-IV characterizations. A 8x75μm AlInN/GaN HEMT model was designed and particularly validated in large-signal pulsed RF operation. It is also shown that thermal and trapping effects have opposite effects on the output conductance, thus opening the way for separate characterizations of the two effects.

Introduction

Gallium Nitride (GaN) High Electron Mobility Transistors (HEMT) on SiC are now recognized as good candidates for the development of a number of RF applications and notably Power Amplifiers (PA) for telecommunications and radars, due to their high breakdown voltage, their high cut-off frequency as well as their high temperature capabilities. However they are still subject to parasitics effects such as thermal effects and especially trapping effects. One convenient way to identify the impact of trapping effects is to monitor the average drain current of the transistor versus an increasing RF input power. Those trapping effects have been extensively studied using a number of techniques such as pulsed measurements, load-pull measurements as well as frequency dispersion measurements. At the same time, models have been proposed that take those effects into account {5296056, Leoni2001, 5516843}, and while the effects of traps are well taken into account in CW conditions, their impacts on

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***Abstract*—We propose here a non-linear GaN HEMT model for CAD including a trapping effects description consistent with both small-signal and large-signal operating modes. It takes into account the dynamics of the traps and then allows to accurately model the modulated large signal characteristics that are encountered in telecommunication and radar signals. This model is elaborated through low-frequency S-parameter measurements complementary to more classical pulsed-IV characterizations. A 8x75μm AlInN/GaN HEMT model was designed and particularly validated in large-signal pulsed RF operation. It is also shown that thermal and trapping effects have opposite effects on the output conductance, thus opening the way for separate characterizations of the two effects.**

I. Introduction

Gallium Nitride (GaN) High Electron Mobility Transistors (HEMT) on SiC are now recognized as good candidates for the development of a number of RF applications and notably Power Amplifiers (PA) for telecommunications and radars, due to their high breakdown voltage, their high cut-off frequency as well as their high temperature capabilities. However they are still subject to parasitics effects such as thermal effects and especially trapping effects. One convenient way to identify the impact of trapping effects is to monitor the average drain current of the transistor versus an increasing RF input power. Those trapping effects have been extensively studied using a number of techniques such as pulsed measurements, load-pull measurements as well as frequency dispersion measurements. At the same time, models have been proposed that take those effects into account [1], [2], [3], and while the effects of traps are well taken into account in CW conditions, their impacts on dynamic large signal characteristics remain difficult to understand. They manifest themselves under modulated signals such as RF pulses or telecommunications signals. In this paper we propose to investigate the dynamics of those trapping effects using large signal pulsed load pull measurements as well as low frequency dispersion measurements. It will be shown that a consistent nonlinear model can be obtained that allows to describe the full dynamic behavior of GaN transistors. The paper is organized as follows: Section II describes the theoretical impact of traps on the average current obtained under pulsed load pull conditions. Section III presents the measurements performed on an AlInN/GaN 8x75μm HEMT and the results

II. The Impact of Traps on Signal Characteristics

One convenient way to identify the impact of trapping effects is to monitor the average drain current of the transistor versus an increasing RF input power. It has already been reported in [1] and [3] that this drain current under class-AB conditions decreases as the input power increases, contradicting the expected characteristics. Clearly this behavior cannot be explained by thermal behavior as far as the channel temperature sinks when the power increases and would leads, at least for moderate powers, to an average drain current enlargement.

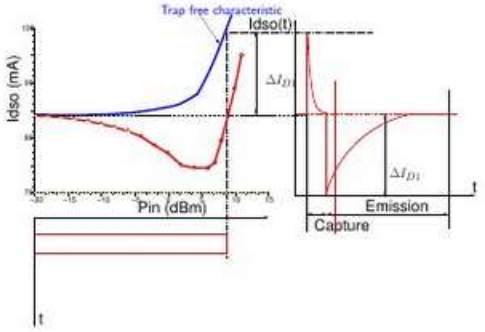

Figure 1. Representation of the mechanism induced by traps on the average drain current.

Pulsed RF measurements were performed under DC bias on AlGaN/GaN and InAlN/GaN HEMTs of 8x75x0.25μm^2 for a large number of output loads. For all devices, we obtain the same shape of the average drain current which is shematized in Figure 1. The average current decrease is due to the trap capture, which increases alike to the gate and drain voltage excursions versus the input power for a CW measurement. Indeed, the number of ionized traps is roughly proportional to the maximum value of the drain-source voltage, because of the disymmetry of the capture and emission time constants [4]. When the RF power is pulsed, the average drain current

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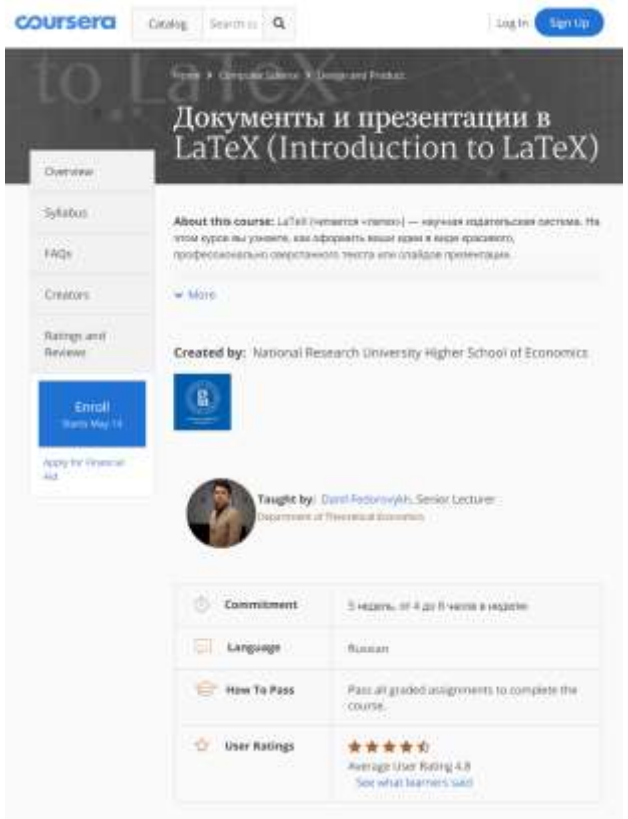

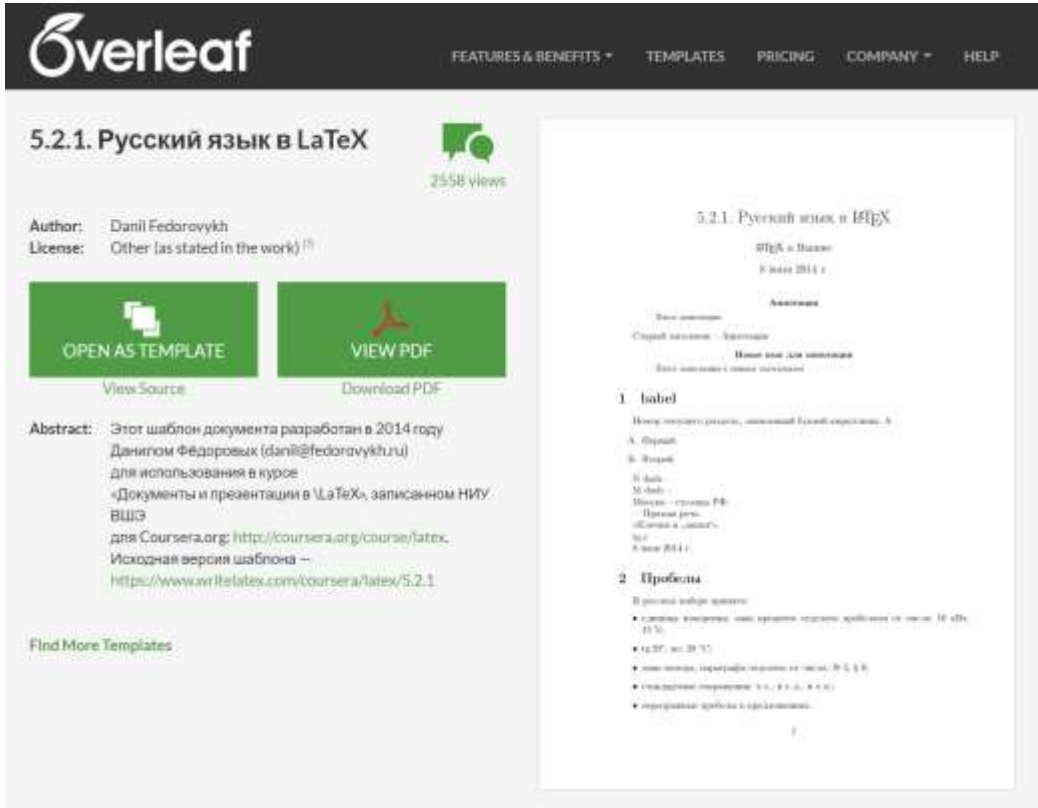

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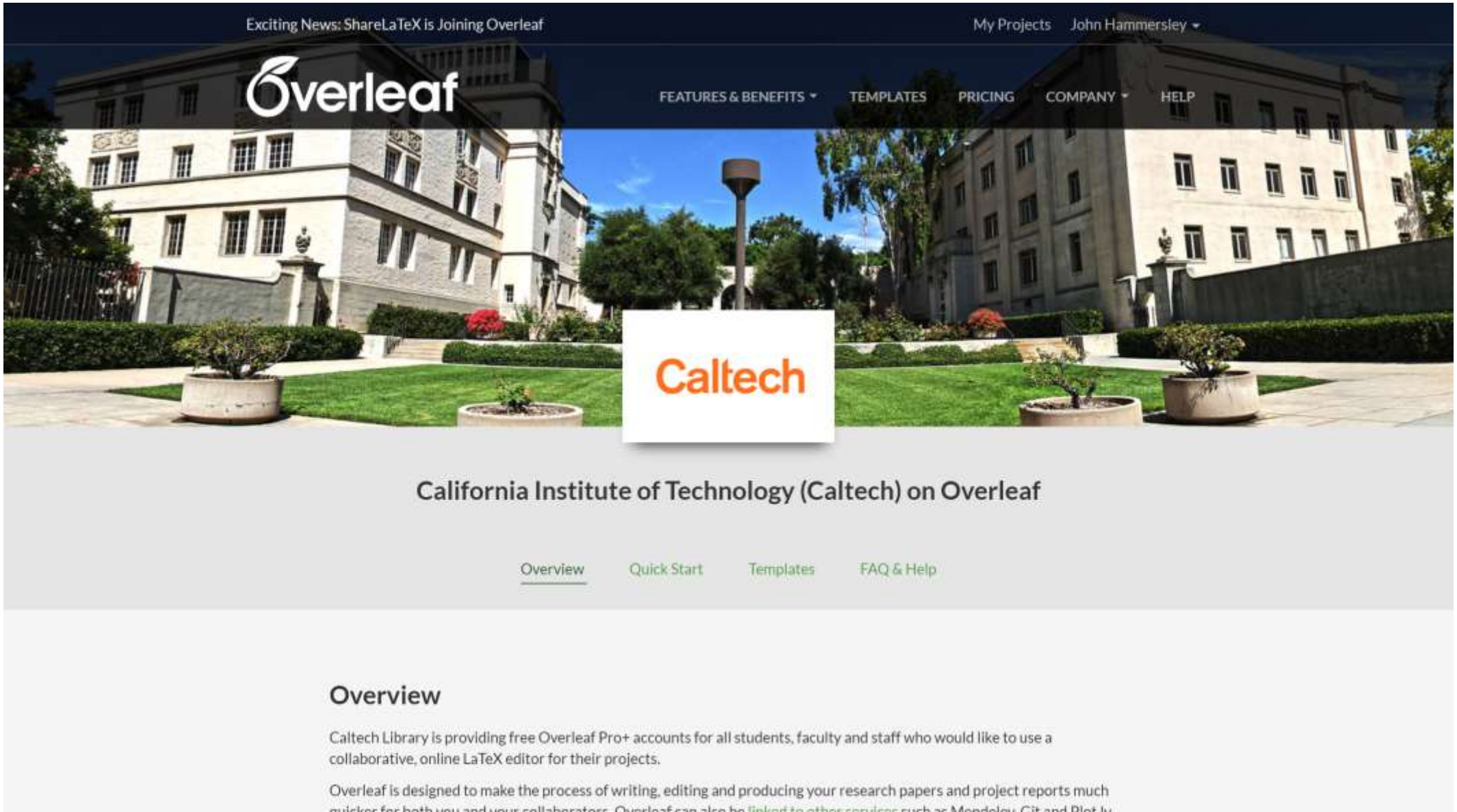

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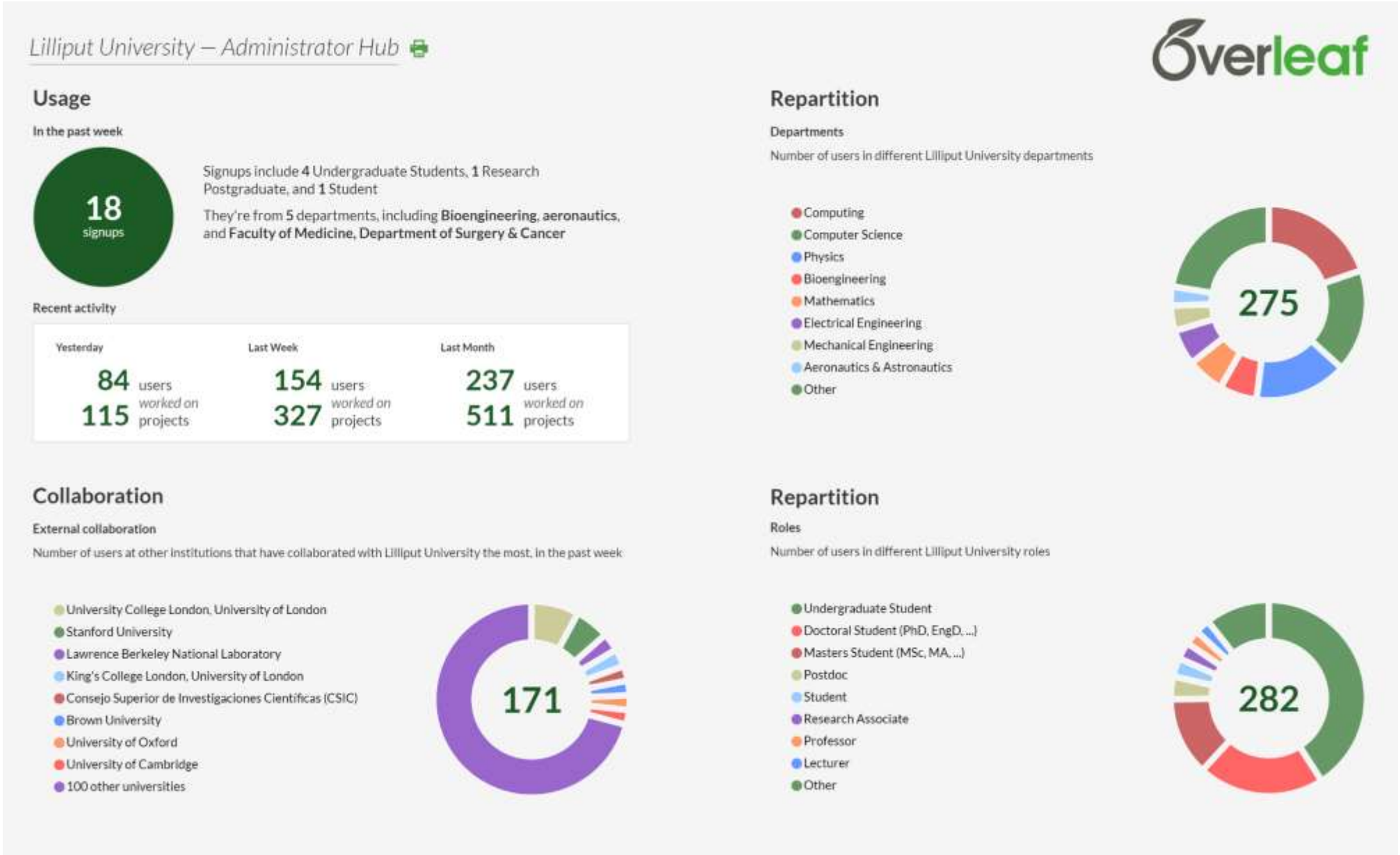

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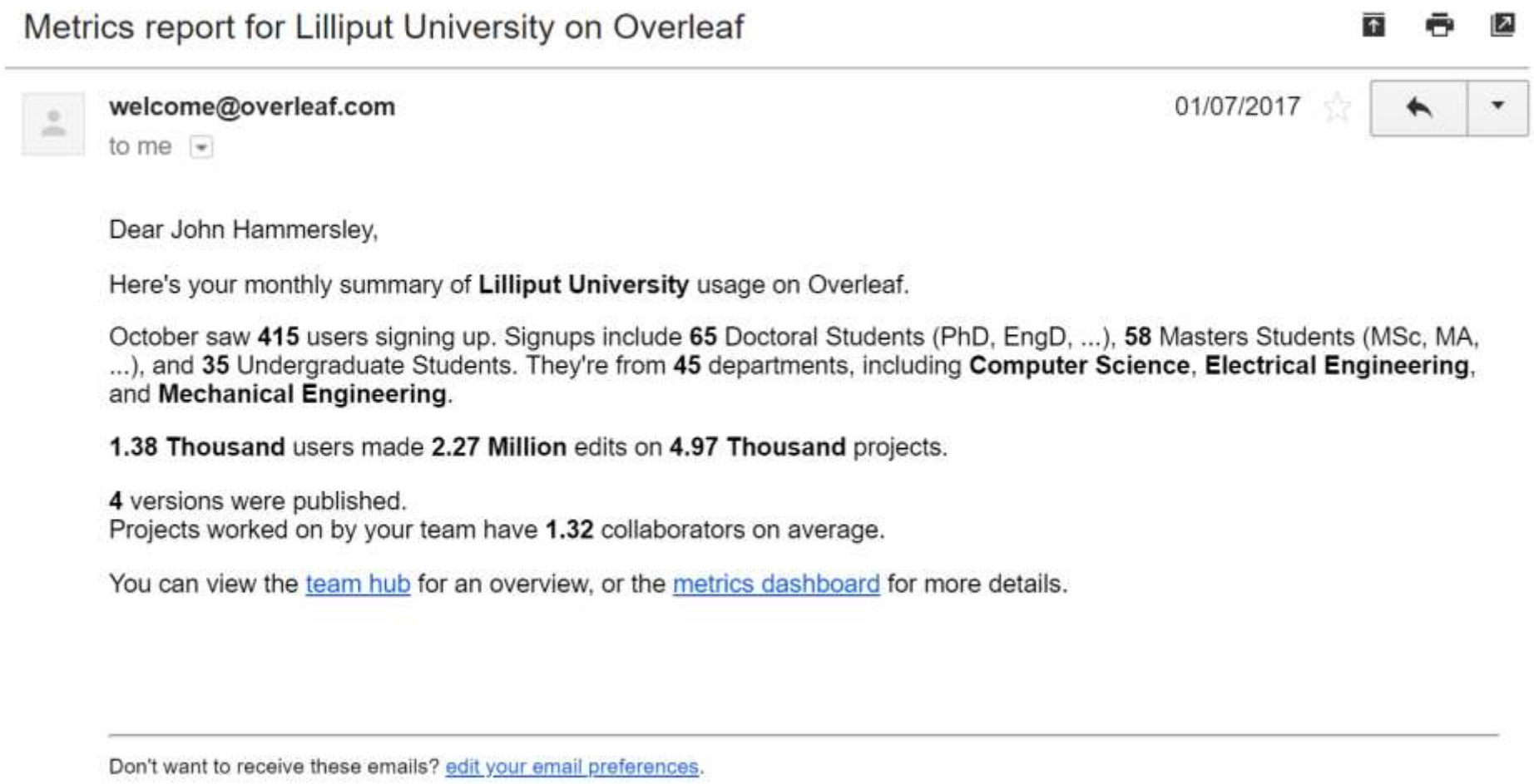

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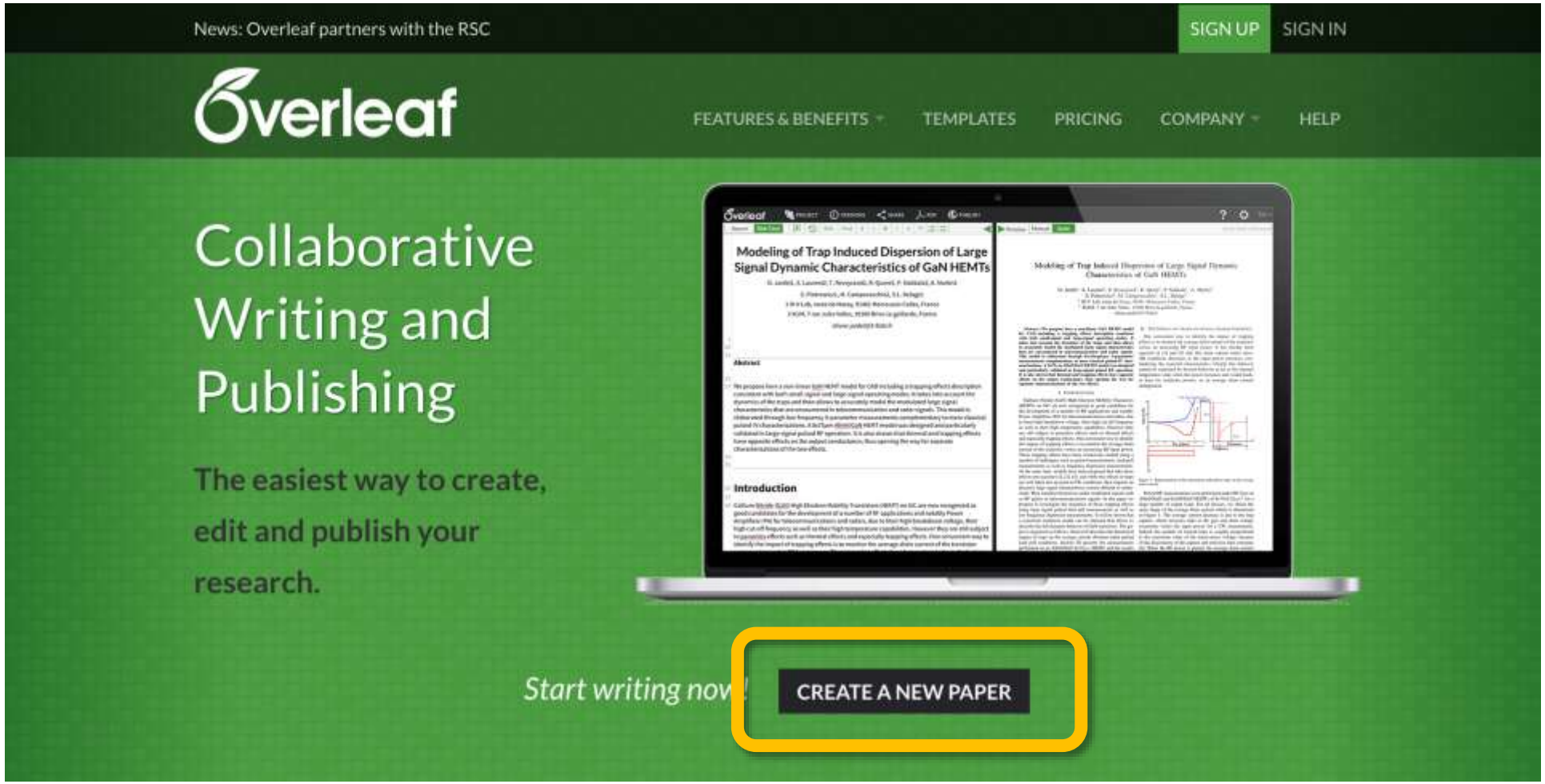

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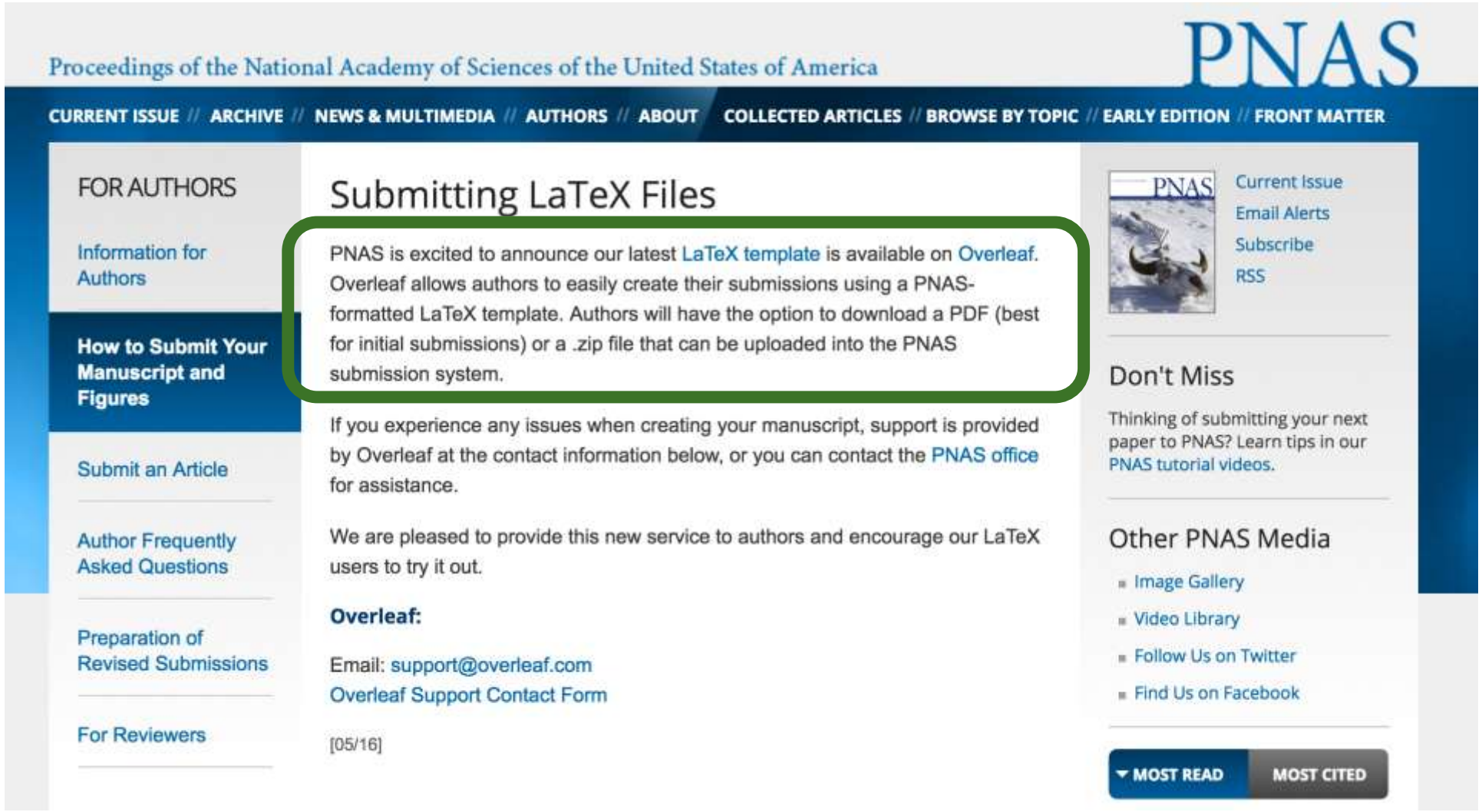

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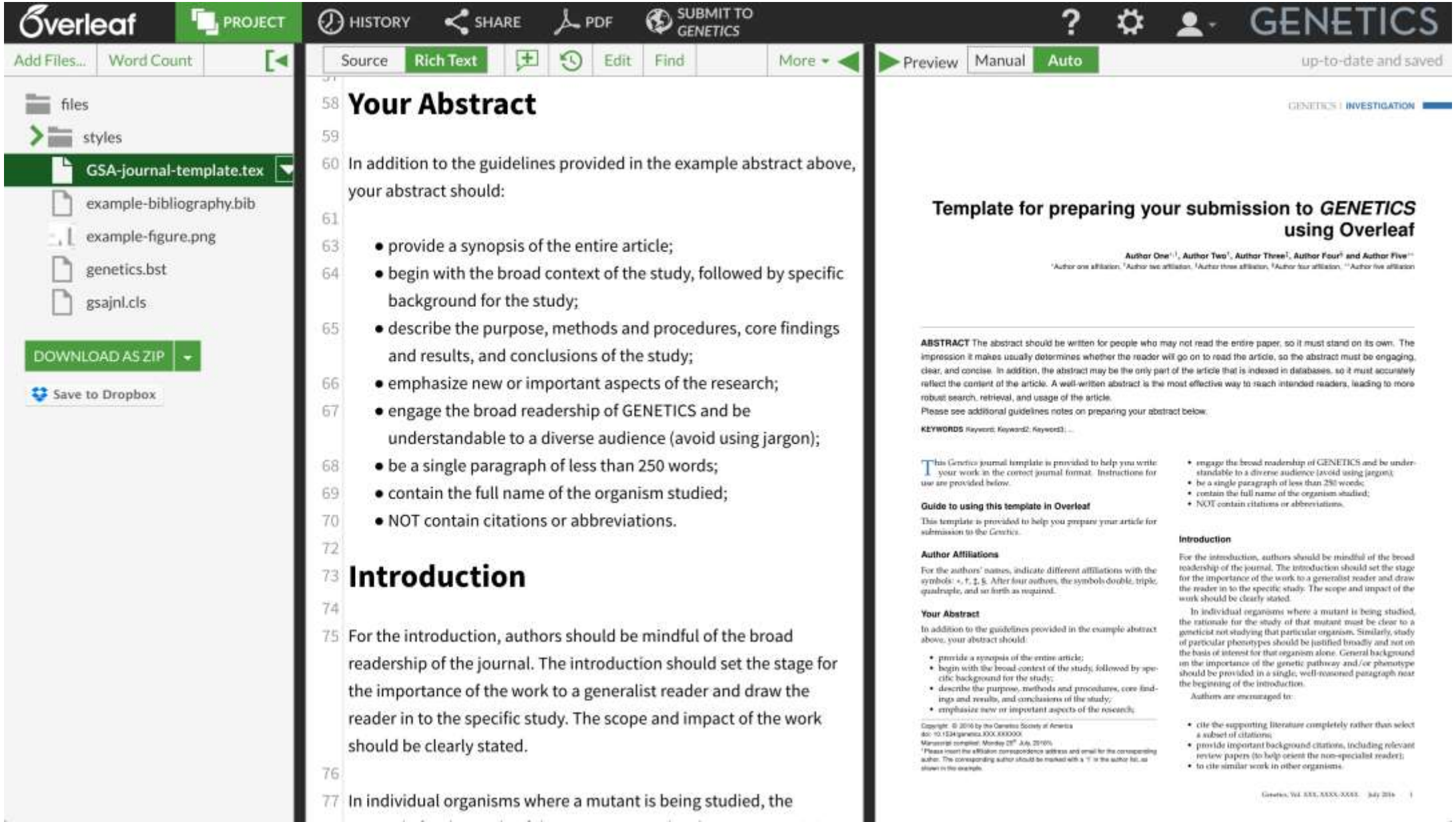

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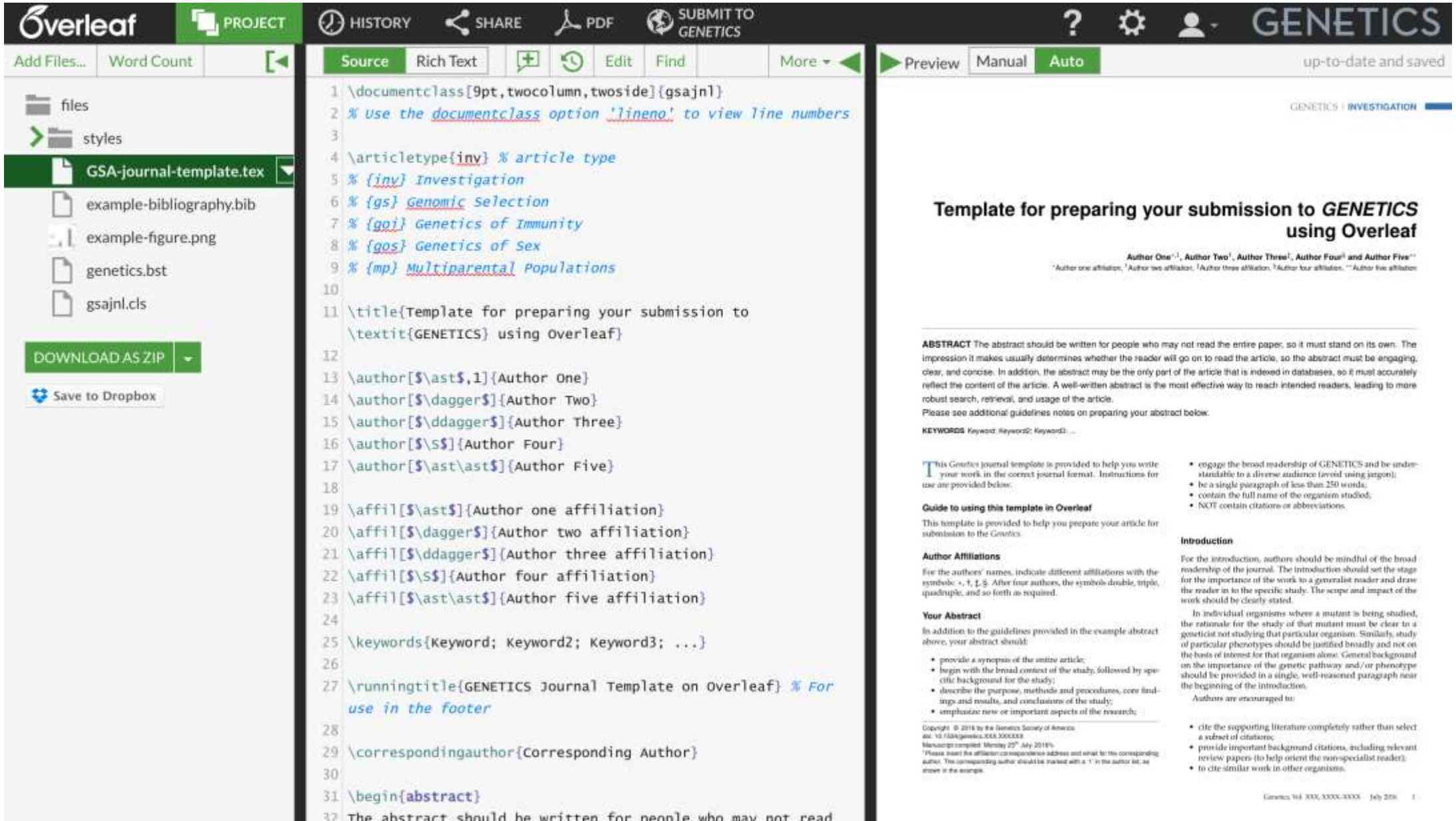

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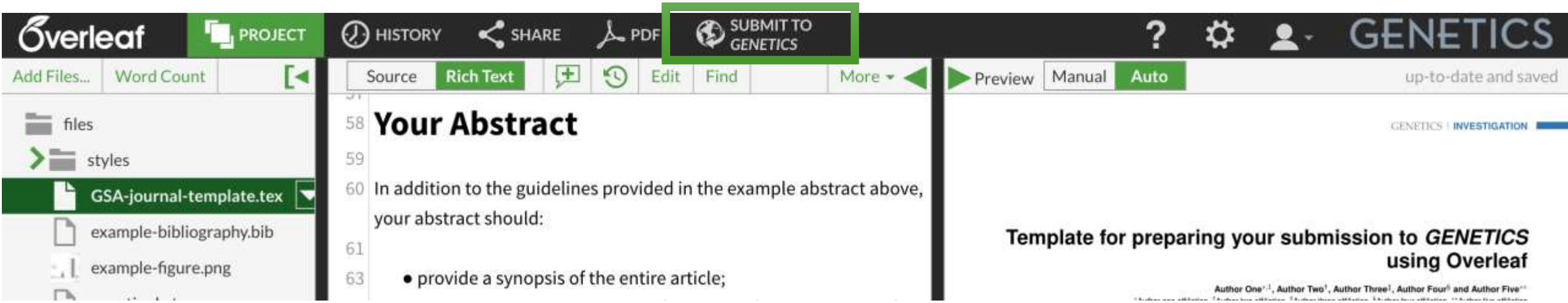

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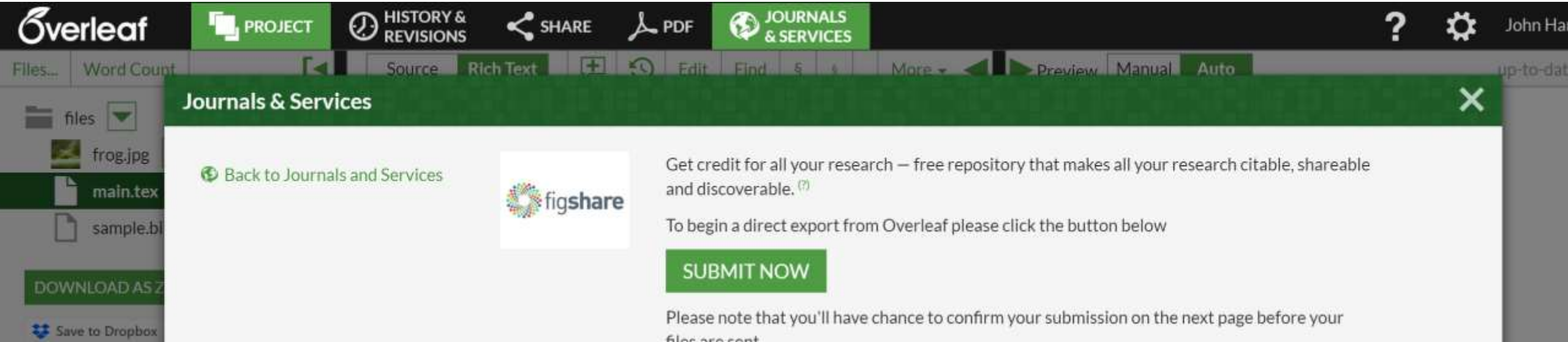


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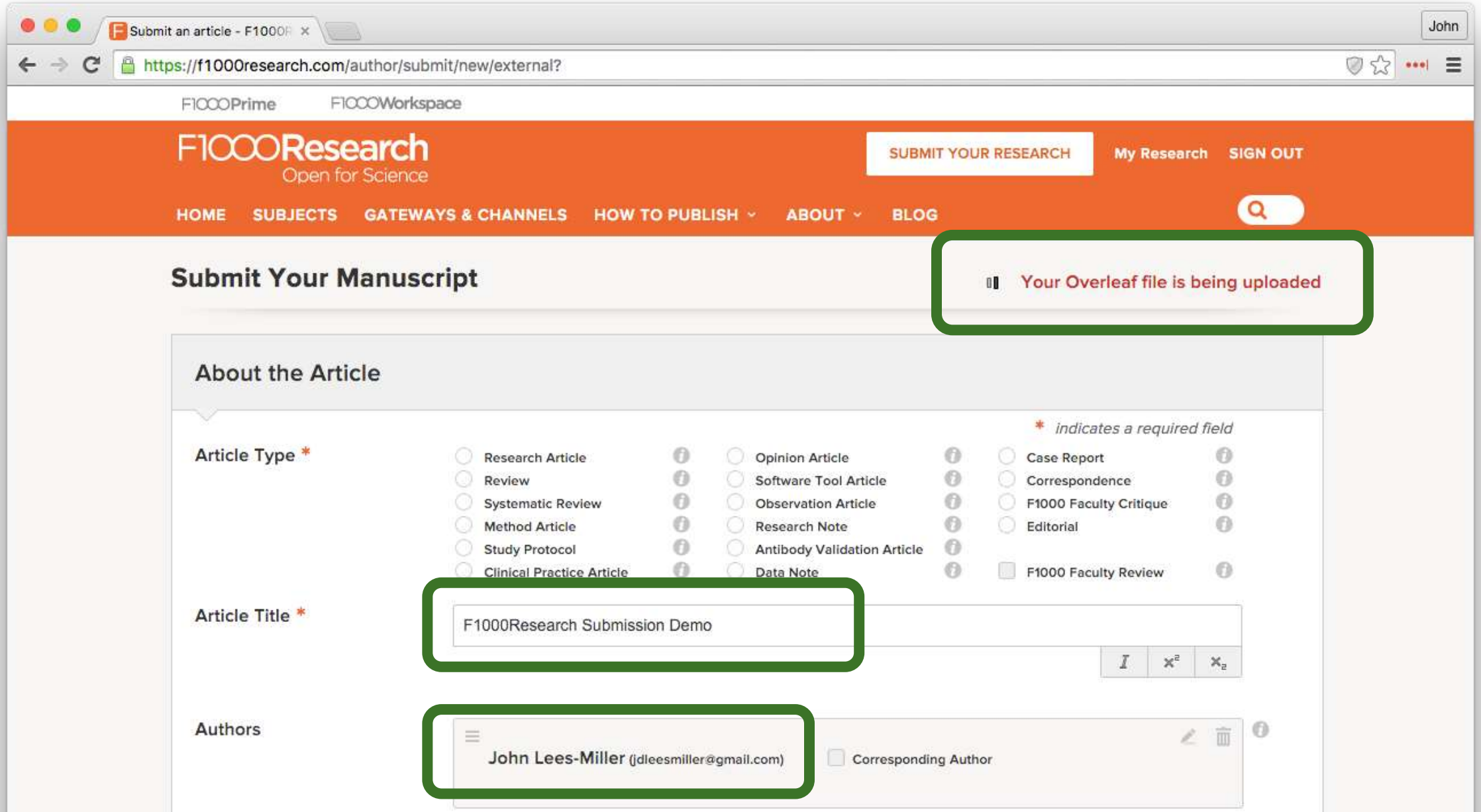

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[1]mcrusoe@msu.edu, Microbiology and Molecular Genetics, Michigan State University, East Lansing, MI 48824, USA

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Jairo Calderari de Oliveira Junior, Raphael Moreira Beirigo, Mariane Chiapini, Alexandre Ferreira do Nascimento,

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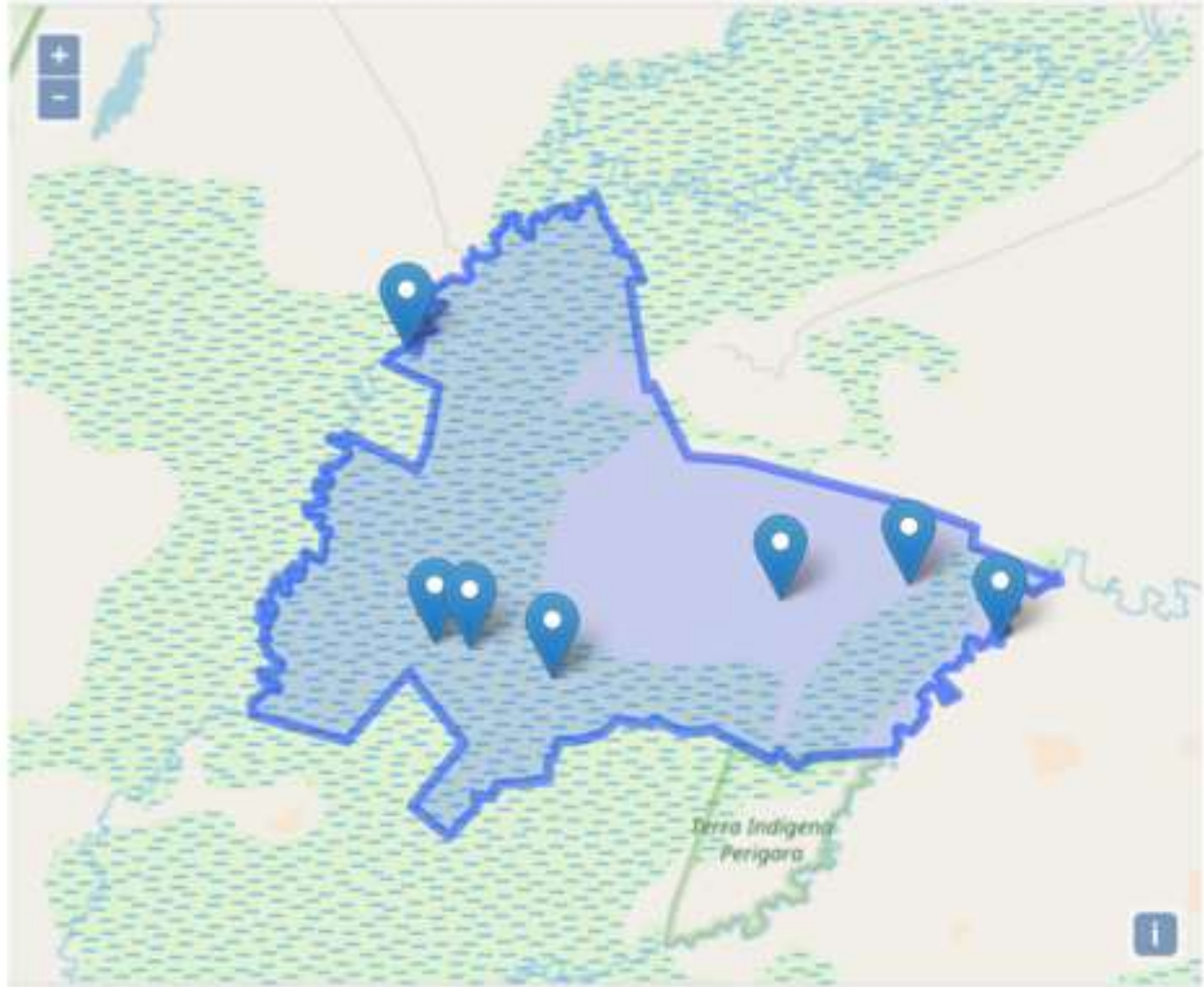

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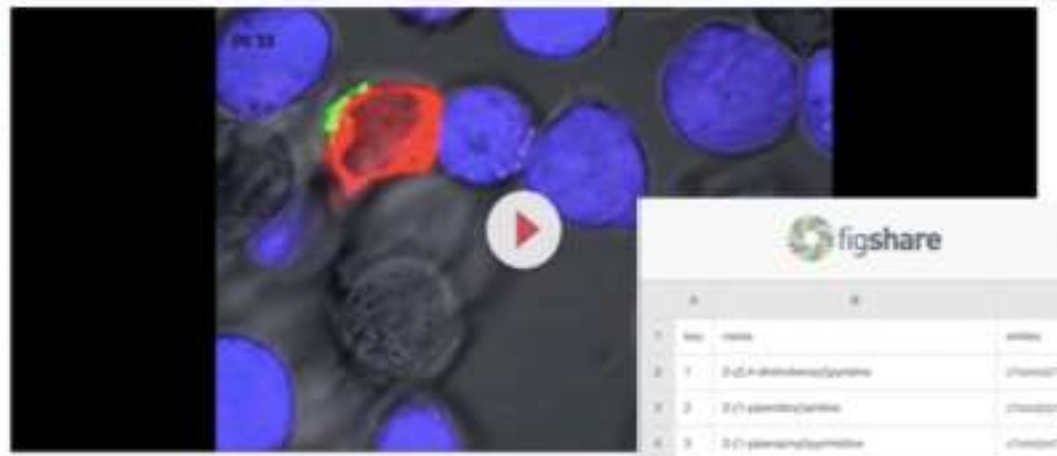

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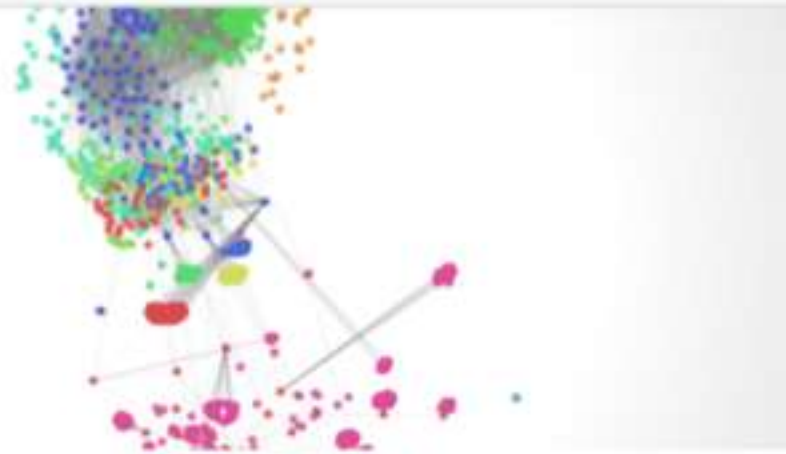

Mapping the Structure of the Archaeological Web

A fileset to accompany an article in a special issue of *Internet Archaeology*. In this article, I map the structure of the web to understand the context of archaeological blogging.

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In [9]:
```
data = words
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figPDF = powerlaw.plot_pdf(data, color='b')
powerlaw.plot_pdf(data, linear_bins=True, color='r', ax=figPDF)
####
figPDF.set_ylabel("p(X)")
figPDF.set_xlabel(r"Word Frequency")
figname = 'FigPDF'
savefig(figname+'.eps', bbox_inches='tight')
#savefig(figname+'.tiff', bbox_inches='tight', dpi=300)
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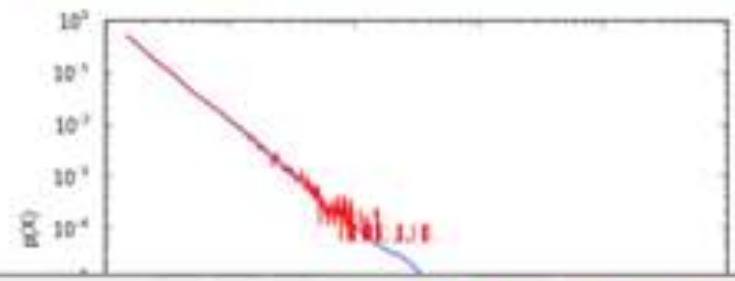

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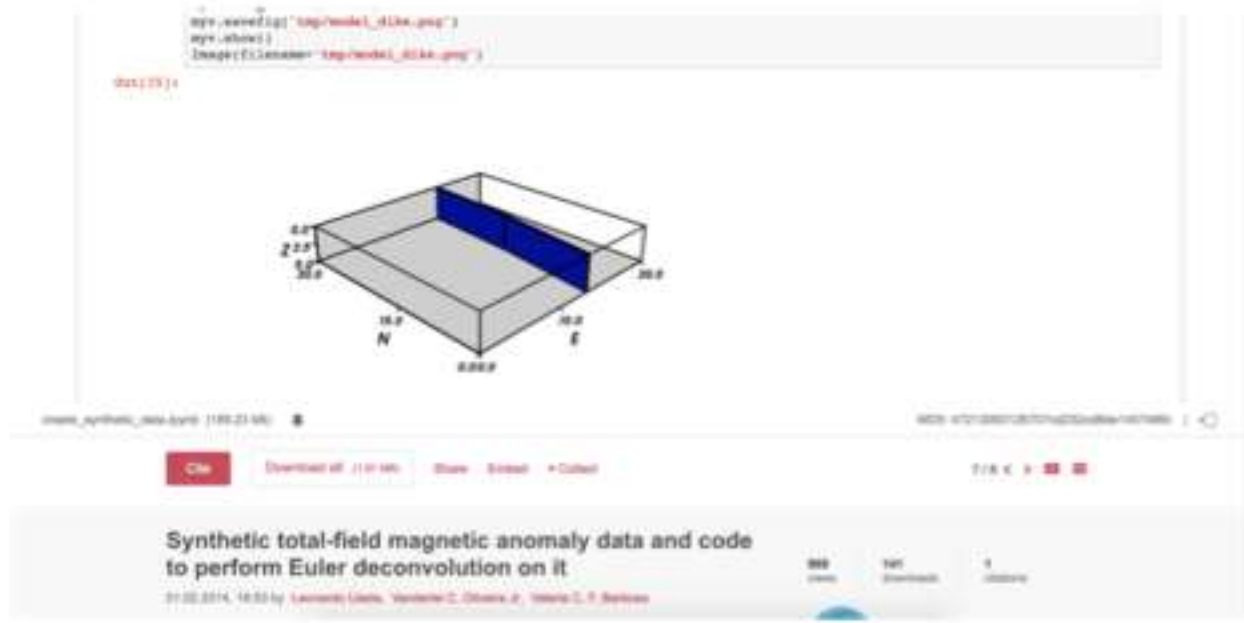
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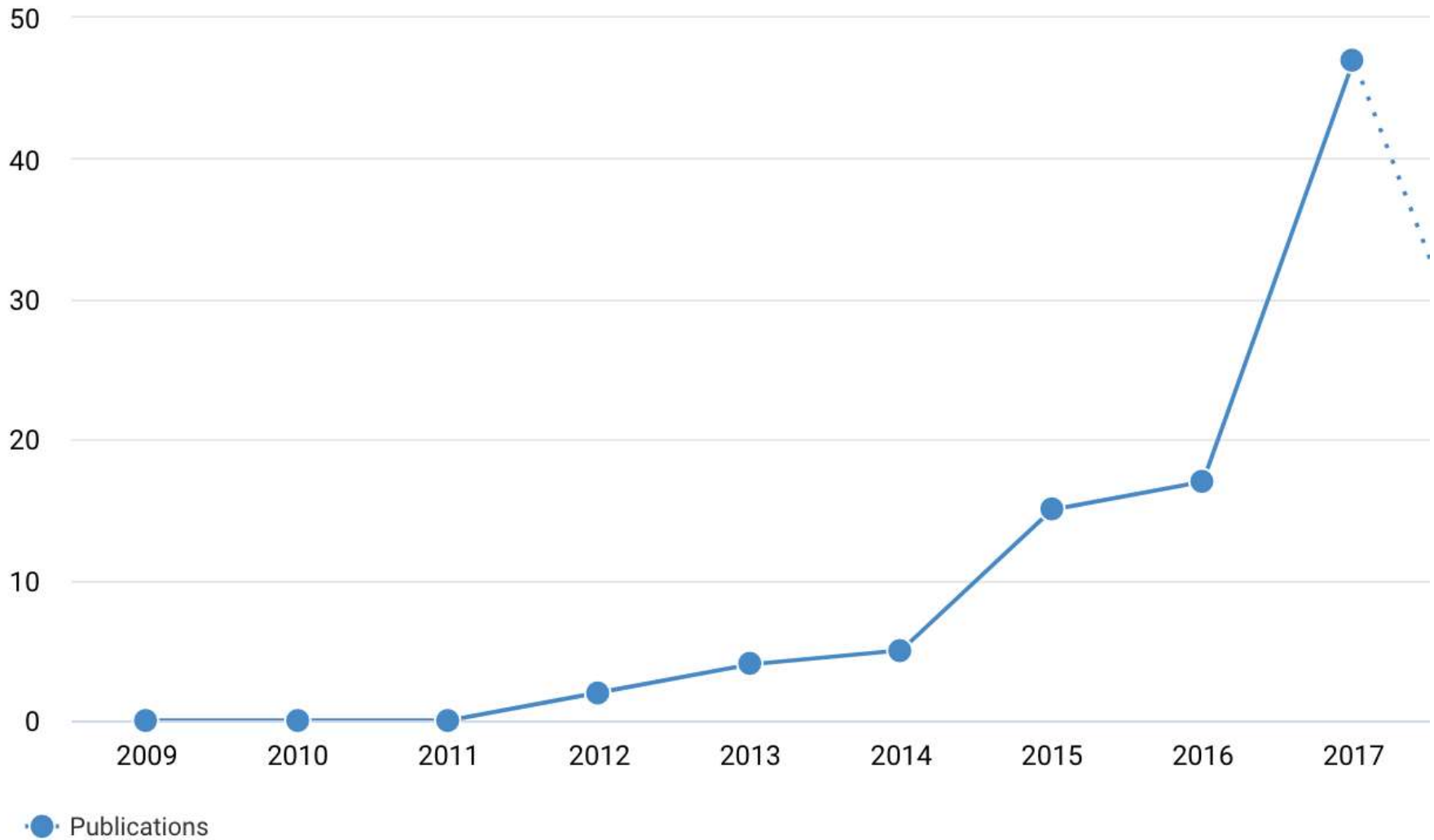

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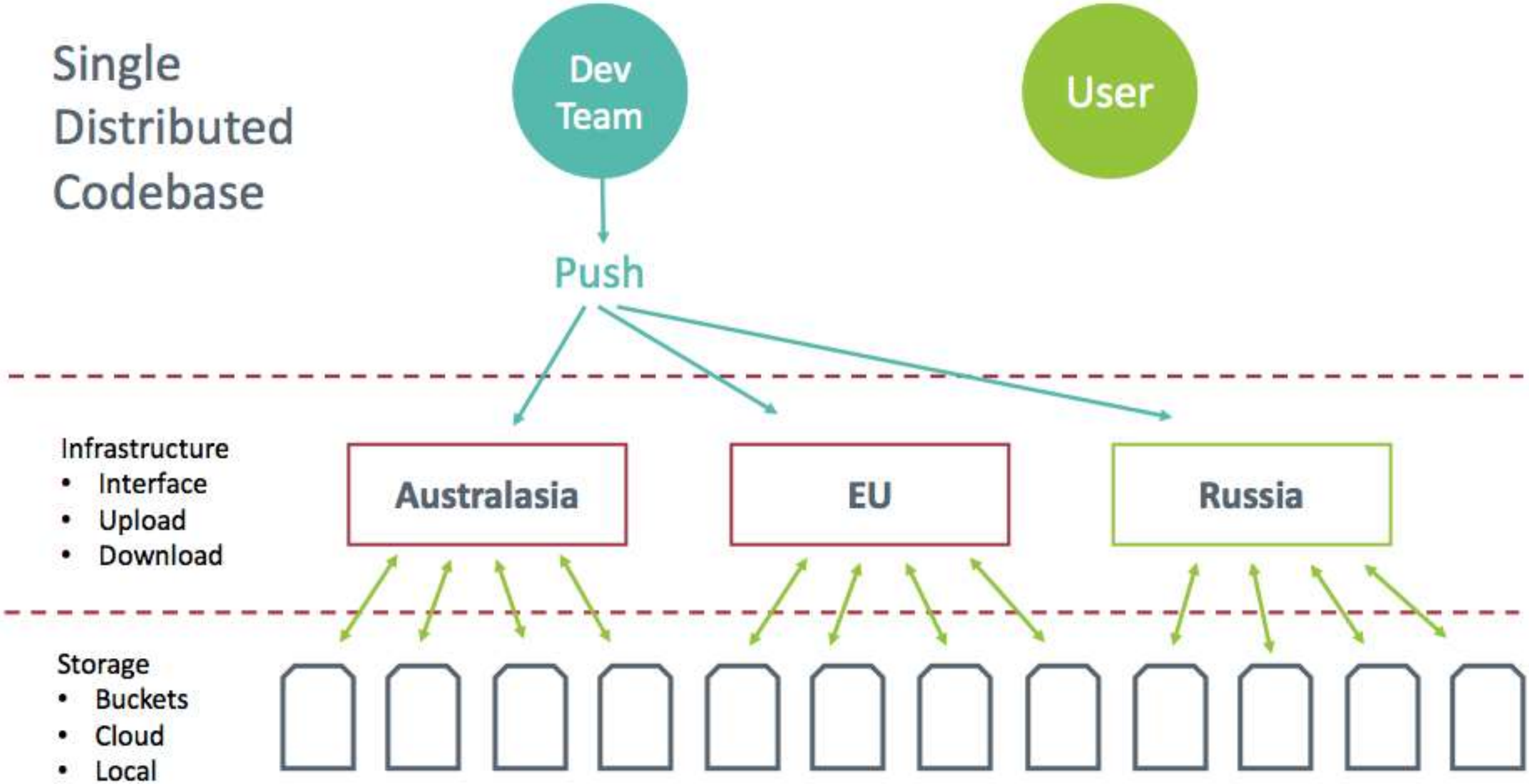

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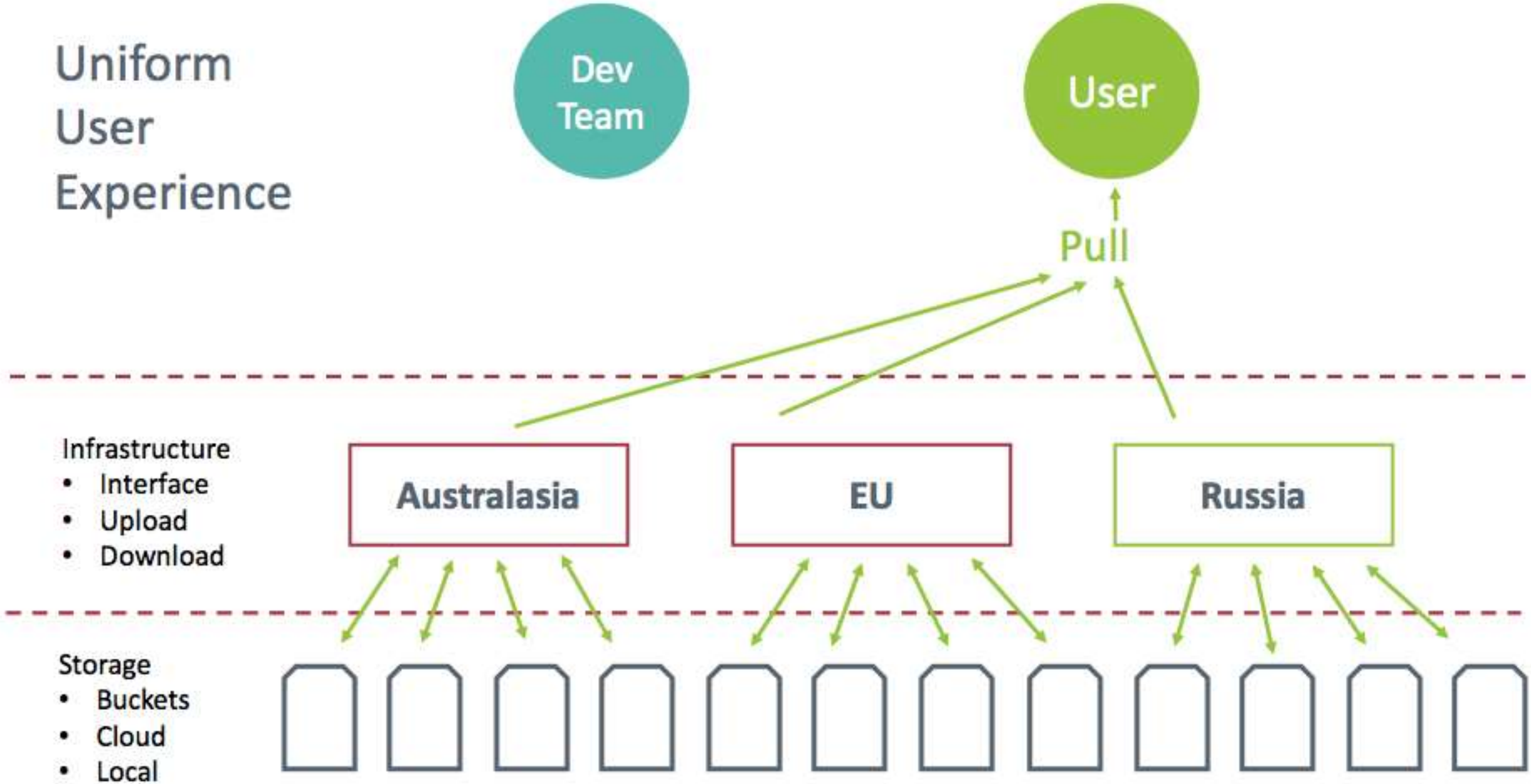

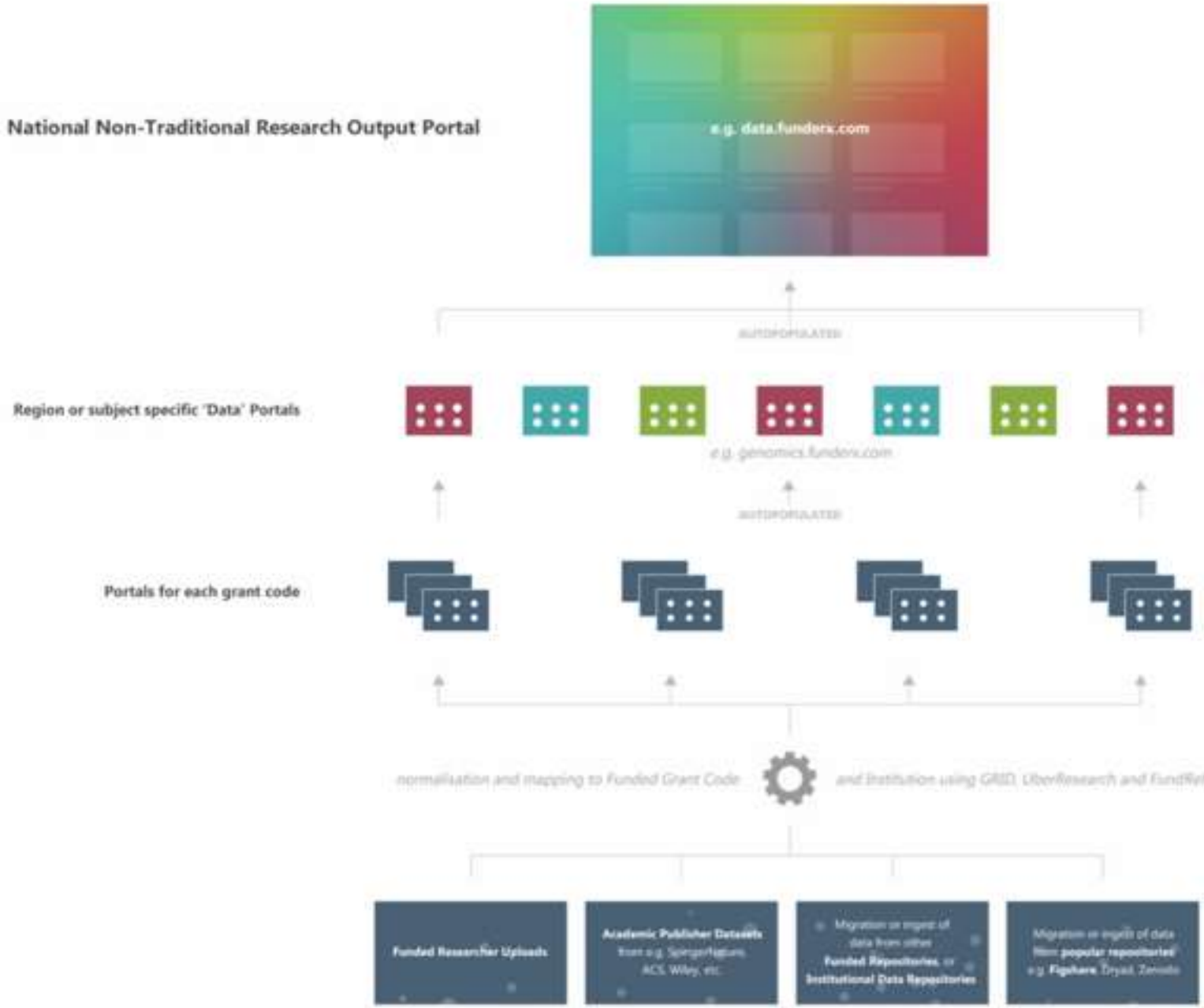
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