

Vector Raptor Overview

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Installation, Data Loading, FEM Layout and Graphics

Please see the TEA Systems note “Getting Started with TEA Systems Products” for this information.

You can download this article from:

http://www.teasystems.com/GettingStarted_TEAproducts.pdf

Topics include:

- 1) First Product Installation, Product Upgrades & Removal
- 2) License Installation
- 3) Initial Data Loading for Importing of Raw Data and Weir Data Workbook formats
- 4) Graphic Interface for Focus Exposure Matrix (FEM) Layout Entry of Data
- 5) Working with Graphics and Plots
- 6) Data Culling Overview
- 7) Hardware and Software Requirements of the tool.

Note: Vector Raptor Analyses are directed toward overlay and registration data. However, any form of metrology data can be imported and analyzed. You can then use you own models to discover process or tool-systematic responses in the data.

Vector Raptor (VR) Toolset

VR analysis tools contain several tools for the engineer and production. Each of these interfaces can be reached from either the Windows Menu shortcuts installed with the software, or through menu calls in each interface.

Note: Choosing the “VR Select” program call from the Windows Programs directory provides selected menu access to any of these programs.

Interface	Function
Vector Raptor	Overlay data analysis & modeling

Interface	Function
	Precision Analysis Metrology Covariance
VR Layout	Enter or modify focus, dose, Numeric Aperture, Partial Coherence (Sigma) and Scan-Direction layout information. Create and save FEM templates for each definition of new data. These are then used by VR and other interfaces to define the FEM layout. Manual entry of Bayesian layout information such as profile descriptions Graphic modification of data-header information such as die-size and centering on the field and substrate.
VR Model Editor	VR Models are stored in the workbooks located in the “Models” subdirectory of the installation. The Model Editor provides a graphic interface for model creation and editing.
VR Matching	Side-by-side comparison and modeling of two datasets.
VR Reticle Subtraction	Subtract reticle data from a dataset to create a new data workbook for VR modeling. Two datasets can also be subtracted for matching purposes.
Daily Monitor (DM) Setup	Create analysis scripts, sometimes called “Macros” from any Vector Raptor product to automate an analysis sequence for production. Scripts are stored in template workbooks whose names end with “.XLT”. The Daily Monitor interface then runs the scripts.
Daily Monitor	Run VR scripts to automate any analysis. This is an ultra-simple interface for production or repeated analysis use. Any complex VR analysis sequence can be duplicated by selecting a data set and pressing one button. Supports Batch Processing. Analysis result history is stored in the workbooks and accessed through automated trend charts. Call interface for other programs and full automation. User selected data can be output to other programs.

You can import raw or load Weir Workbook Format data by using the toolbar menu commands or by pressing the appropriate button. Tool-tips provide instant information on toolbar button functions.

Raw or workbook data can also be dragged onto an interface for loading. If raw data is loaded the import filter defaults to the last-used data. Raw data is imported into a Weir Data Workbook format. Subsequent analyses of the data should use the workbook that will also store a history of analysis results and reports.

The Vector Raptor interface provides the major capabilities for data visualization, systematic error extraction and process or tool correction. Systematic error models are provided with the software. VR analyses are supported by tools that allow the proper setup of FEM layouts while others provide matching and data subtraction capabilities.

VR Models can be modified or new models created using the graphic VR Model Editor tool.

The VR Reticle Subtraction interface provides an optional capability to subtract two datasets or remove reticle-data from the measured data. Some visualization tools are provided and comparative reports are created. The output of the interface is stored in a Weir Data Workbook and can be loaded into Vector Raptor for more in-depth analyses.

VR Matching is a stand-alone interface that provides additional tools for the comparison of two datasets

VR analyses are automated for production or repeated use with the Daily Monitor program.

Vector Raptor

Concept

Vector Raptor provides an interface for the analysis, correction modeling and metrology evaluation of data. When data is loaded, the Data Selection interface will be brought to the forefront. Data can then be visualized and sub-sets, restricted by exposure or behavior, can be selected for analysis. The user can also interactively remove data points or field-sites using the mouse. After selection the analysis moves to the Spatial or Metrology interfaces.

Systematic error modeling and data visualization tools are located in the “**Spatial**” interface tab. Spatial models are used to determine error sources based upon their characteristic responses. For example, process, bake, develop and wafer-setup errors result in spatial signatures that slowly change across the wafer or lot. Exposure or field-leveling problems introduced by the exposure tool will appear as whole field oriented signatures. Reticule-stage scan errors appear as systematic perturbations along the columns of data in each field and optical or lens errors along the rows the reticle. VR Models adjust automatically to the application of the data. Models can be applied to the wafer, field, row or column to quantify the signatures of each error source.

Vector Raptor Spatial analyses automatically graph and characterize the response of modeled variables to focus and dose variation. Feature designs or double patterning layers are delineated using “Family” designators by site and are comparatively modeled for response analysis.

The “**Metrology**” tab is used to compare the statistical behavior of the data. **Precision** analyses break down data response in the form of the standard error, or “One-Sigma”, precision of each variable. Variances are calculated based up the variable populations as grouped by wafer, field, site, row and column location in the data. An analysis of these variances yields a quick evaluation of metrology tool, process or exposure error sources.

The **Covariance** analysis calculates the statistical covariance variables in the data. This simple interface provides tools to graphically compare variable response with other variables or with exposure or with the order in which the feature was measured. Covariance analyses are highly useful in the evaluation of proper metrology recipe setup or to discover variable cross-dependencies. This is a highly precise tool for the evaluation of Electrical or Ellipsometric Metrology and RCWT model response.

Data Selection Details

The data selection interface, figure OV1, provides tools for the initial visualization of data and subset selection. The commands contained in the button bar at the top of the interface provide rapid menu access for data printing, viewing or loading. There are three drop-down or “combo” controls on the right side of this button bar. These controls provide selection of data for viewing or analysis by using variable names, family designators and the loading of additional datasheets located in the workbook that will be created as analyses are performed.

The controls located below the button bar provide the initial data sub-set selection and culling by wafer, exposure and variable range. The ‘Select Data’ command button at the bottom of the screen, under the field graphic, implements the culling detailed by selections on these controls.

The two graphics screens at the bottom of the interface provide information on the layout of

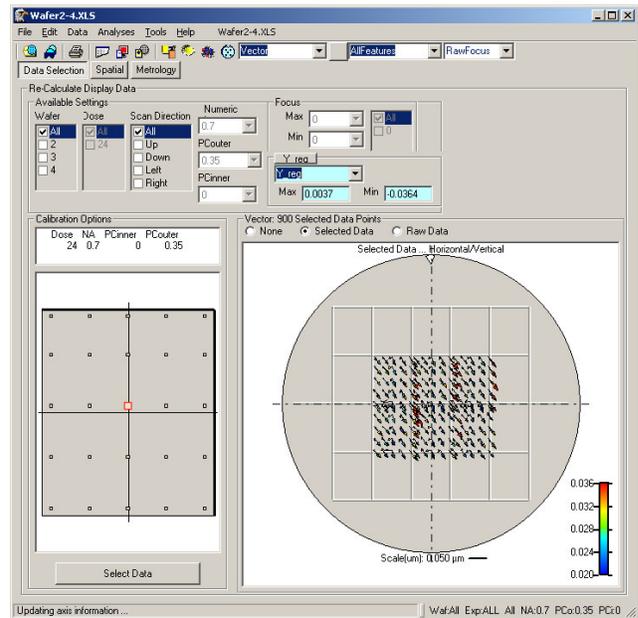


Figure OV1: Data Selection interface of Vector Raptor

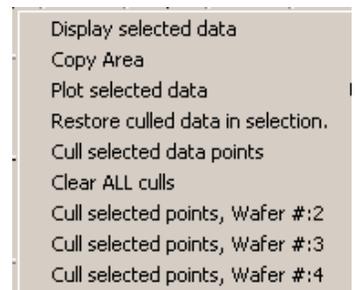


Figure OV2: Mouse Pop-Up

field-sites and data on the wafer. These graphics will immediately reflect the data culling results. The data plotted on the wafer graphic is selected using the variable selection combo control at the top-center of the interface, set to “Vector” in figure OV1.

Data culled from the field-site graphic will remove each site’s data from analysis. Points selected on the wafer-graphic remove individual values or, for multi-wafer data sets, an entire wafer of data.

The mouse can be used with these graphics to view data subsets, create graphic plots or cull (or restore) additional data points. Box in an area of the wafer and select an action from the pop-up menu shown in figure OV2.

Spatial Analysis Details

Graph-type, being ‘Field’ or ‘Wafer’, and the start of the analysis is performed by selecting one of the tabs to the left of the graph-field.

A ‘**Cull Radius**’ command button and field culls data points by restricting the data to only those points that are within the entered radius value in mm from the center of the wafer. Pressing the ‘**Radius**’ **Command Button** will generate a radial analysis graphic and report showing the radial distribution of data on the wafer. A report is stored in the data workbook.

Spatial Analysis Tab

The **Spatial Analysis** tab, located above the graphic, provides data visualization for raw or systematic variable response.

The “**Display Selection**” sub-tab, shown in figure OV3, defines what will appear on the graphic and the type of graphic. Vector, histograms, contour and surface plots are available.

Graphic and statistics components are turned off/on using the check-boxes to the left of the upper interface. The graph limits are set to the maximum ranges of the variables unless the ‘**Optimize**’ check-box is selected. When the graph is ‘optimized’ then the graph display ranges are set using the maximum ranges specified by a box-plot analysis of the populations thus avoiding the strong biasing provided by soft data errors.

The variables analyzed are selected using the drop-down combo located at the top of the interface and discussed in the previous section. The variable actually plotted is selected using the ‘**Plot Feature**’ drop-down combo located in the center of the interface next to the check boxes.

The ‘**Scale**’ field allows the user to specify the scaling used on the graphic. When a 2-D vector plot is created, the Scale field is specified in the units of measure of the graphic. For example, the Scale value in figure OV3 is set to 0.030 μm and this pins the maximum vector size of the graphic as shown at the bottom of the wafer plot. If a 1-D vector plot is selected, then this value represents the size of the vector-circle on the plot in pixels. A letter printed such as “O” is approximately 90 pixels in size.

Set the ‘Scale’ to zero to allow the graphic to automatically set the plot-scale. You can then modify it from this value using the Graphic Editor that is started by right-clicking on the graph with your mouse.

The ‘**Range**’ and ‘**Sigma**’ control fields provide additional data culling that is performed during data modeling or prior to a raw-data plot. A range value of 0.05 μm will exclude all data points that are greater than 0.05 μm away from the median of the variable’s population. Similarly a sigma value of 1.2 excludes all data that exceed 1.2 standard deviations range from the median of the population.

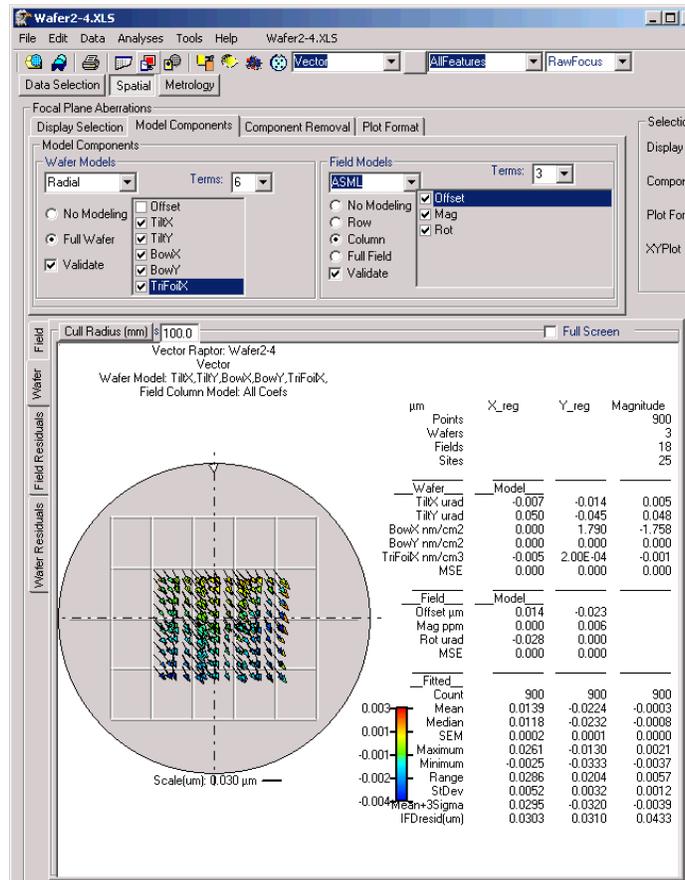


Figure OV3: Display Selection tab for graphic setup

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Pressing the '**Range**' *Command Button* adjacent to the Range Field initiates an analysis of variable population distributions shown in figure OV4. This analysis is presented as a series of graphics that illustrate the number of data points that will be excluded for any Range or Sigma value entered. For example a value of 0.012 entered in the Range field will result in only 200 of the initial 800+ points remaining in the dataset after culling. These points will be restored after the analysis.

Model Components Tab

The details and control of modeling are found on the Model Components sub-tab shown in figure OV5. Each model level, Wafer or Exposure Field, contains:

- A model-selection drop-down combo control,
- A 'Terms' control that allows the number of coefficients included in the analysis to be restricted and
- A check-box listing of the coefficient names that will be included in the statistical output and graphic display.
- The 'Validate' check-box to turn coefficient validation *on* or *off*.

The '**Terms**' control actually limits the number of coefficients included in the modeling while the Coefficient Check-boxes only show, or suppress, the systematic influence of each coefficient on the data. For example if the field 'Mag' coefficient is the only checked value, then the graph and statistics will the only the influence of the 'Mag' coefficient.

When selected, the '**Validate**' checkbox will set a coefficient's value to zero if it is less than the twice standard error of estimation of the coefficient. This is the preferred method of analysis for tool control calculations since it prevents process run-away control resulting from over or under-correction of components.

Component Removal Tab

Remove the influence of the exposure tool prior to data analysis to improve determination of the influence of process or exposure on the data. The controls in this tab, figure OV6, allow field components to be subtracted from the data.

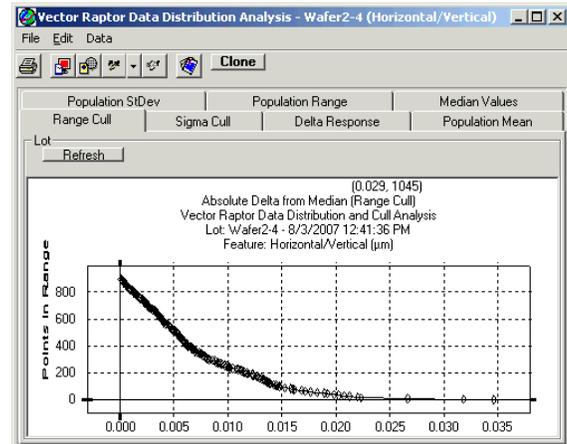


Figure OV4: Range & Sigma response plots

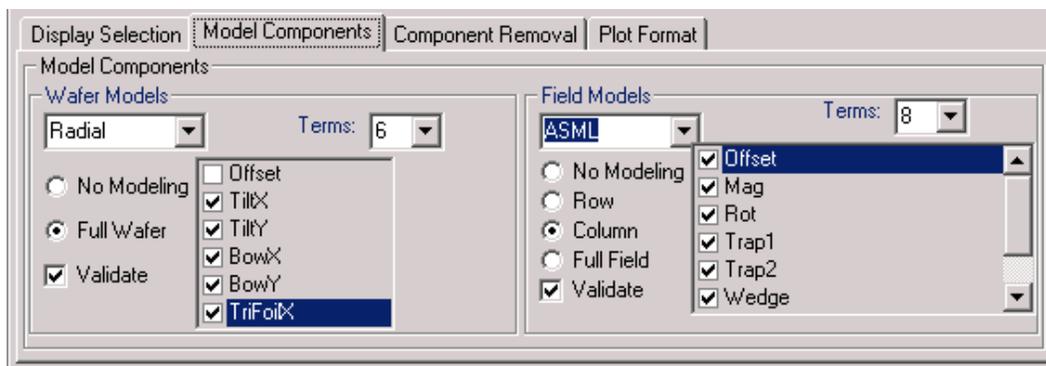


Figure OV5: Model Components Tab

The '**Basis**' drop-down allows the user to select use of the Average or Modeled values for subtraction. When modeled, this data is calculated based upon either a full-field or Row/Column based field model.

When selected, the '**Lot Average**' check box will use the average of all fields in the lot to calculate the average field for the subtraction basis. If it is not checked, then the average for each field is selected and

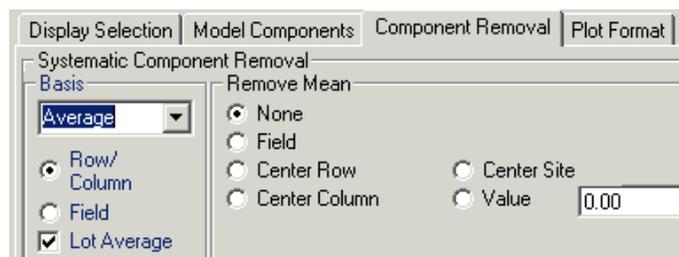


Figure OV6: Component Removal tab

Vector Raptor Overview

subtracted from all the data in the selected field. This control is meaningless if the “*Remove Mean Field*” radio button is selected since it would result in zero values for all data points.

Note: Un-check the ‘*Lot Average*’ control when the data contains focus-exposure variations.

The ‘*Remove Mean*’ radio buttons define what type of data is removed. Removal of the ‘Center Row’ data will effectively remove the variation introduced by the lens-slit signature. Conversely, removal of the ‘Center Column’ data extracts the influence of the reticle-stage scan.

‘*Center Site*’ removal eliminates the field offset, or InterField or stage-stepping errors, resulting in an improved analysis of process and IntraField responses. Finally, any arbitrary value can be entered in the ‘*Value*’ field and removed from the data.

Plot Format Tab

Most analyses simply result in a plot of the data or selected subsets of an analysis. The controls on this tab enhance the visualization of errors in the data. These controls include:

Field Mean	Plots the average value of the field for this grid location.
Field Min/Max	Plots the maximum or minimum of the field for each grid location. The value plotted is based upon the maximum absolute value of the field.
IFD	IntraField Deviation (or IFD) plots the range of values across the field for each grid location.

Ancillary Graphics

A series of pop-up graphics will be generated. These are X-Y graph plots that vary depending upon the type of analysis. Plots include:

Graph	Data or Analysis Required	Description
Data v Wafer	Multi-Wafer dataset	Plot of Raw, fitted and residual data for each variable and family.
Row/Column Fitted	Row or Column modeling of field data	Plot fitted data values based upon row or field location on the field.
Wafer model response	Multi-wafer data set	Plots coefficient variation for each wafer in the lot.

Metrology Analysis Details

This interface provides tools to assist in the statistical analysis of the data.

Precision Analysis Tab

Precision is calculated based upon population sub-divisions by Lot, wafer, field, site, column and row location.

Press the “Analyze” command button to start the analysis. A report is saved in the data workbook.

Covariance Tab

Calculates the covariance of each variable, its serial location in the data and family values in the data.

Graphics are generated when an abscissa and Ordinate values are selected. Multiple variables can be selected for plotting.

VR Matching

Vector Raptor Matching, figure OV7, provides two-dataset comparative statistics and graphics. The approach is to be able to directly compare the response of two datasets. This is an interface under construction however the functions already installed are very powerful.

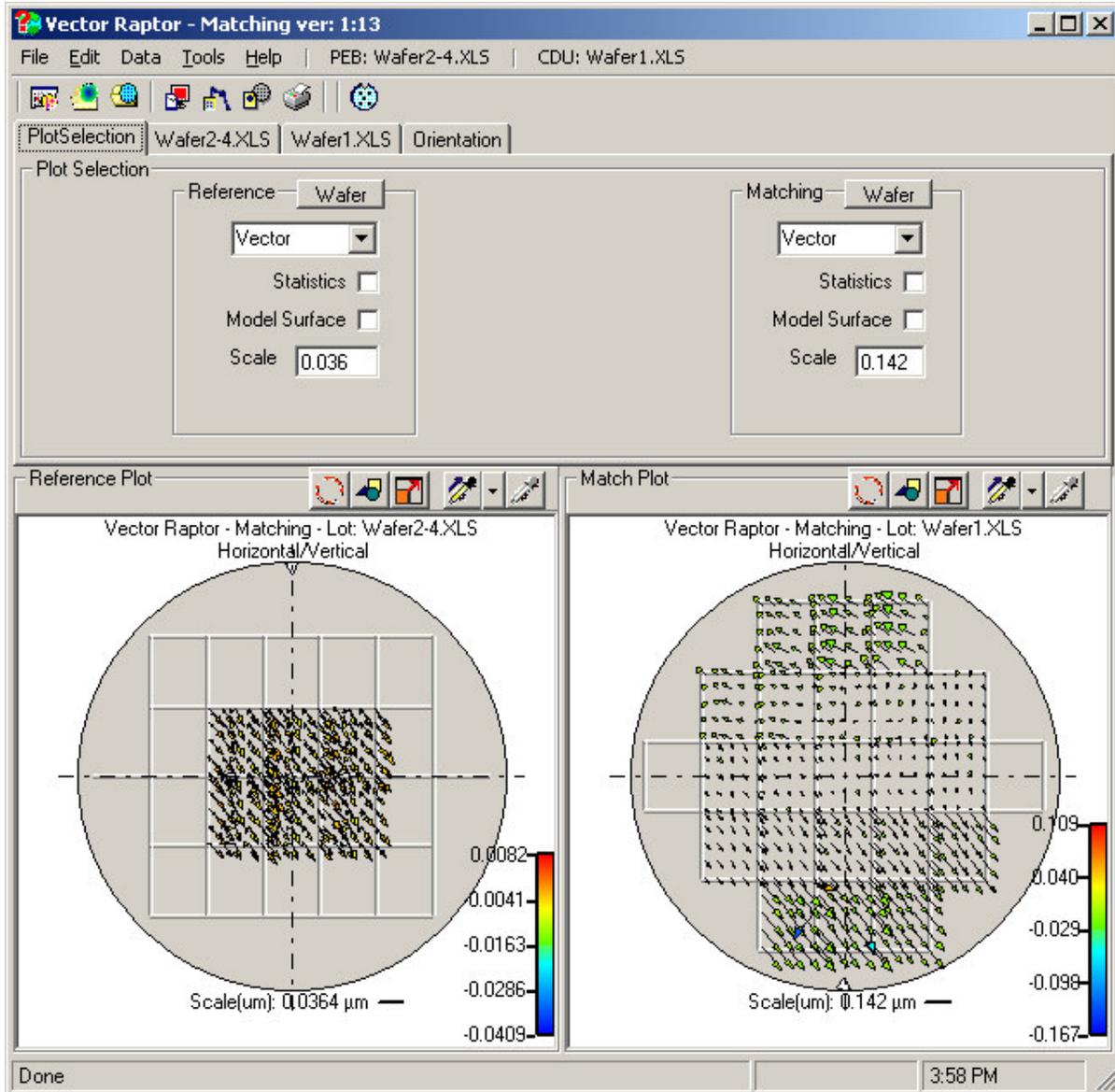


Figure OV7: VR Matching interface.

The interface is intuitive in its approach and mouse-sensitive.

VR Reticle Subtraction

Reticle metrology data or two data sets can be subtracted and entered into a new data file for analysis using Vector Raptor. This interface allows the reticle to be averaged, re-scaled and rotated to set the proper orientation to the wafer-metrology data.

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The resulting data file can be analyzed within the interface or loaded into Vector Raptor for a more detailed analysis. See the recent paper from SPIE that used the interface for profile data to see the methods and controls of the technique. This paper can be downloaded from:

http://www.teasystems.com/Publications/PW/PreciseMeasurement_ProcessBias_SPIE6520_139pub.pdf

and at

http://www.teasystems.com/Publications/PW/FullField%20implications%20of%20MEF_ML%206155-12.pdf