Question 2

Write a program to implement down sampling of an image by a factor of 2 . Apply the same effect for 2 / 3 successive times and comment on visual content. Finally, write a program to upscale the down sampled image through interpolation and comment on visual quality of the image.

In [1]:
```
import numpy as np
import matplotlib.pyplot as plt
import math
```

Images to process

In [2]:
```
path_inp = '../../images/dat/'  # path for input files
path_out_orig = 'originals/'    # path for output files: originals
path_out_conv = 'converted/'    # path for output files: converted

filenames = [
    'f256',
    'l256',
    'o256',
    'p256'
]

ext_inp = '.dat'    # file extention for input
ext_out = '.bmp'    # file extention for output
```

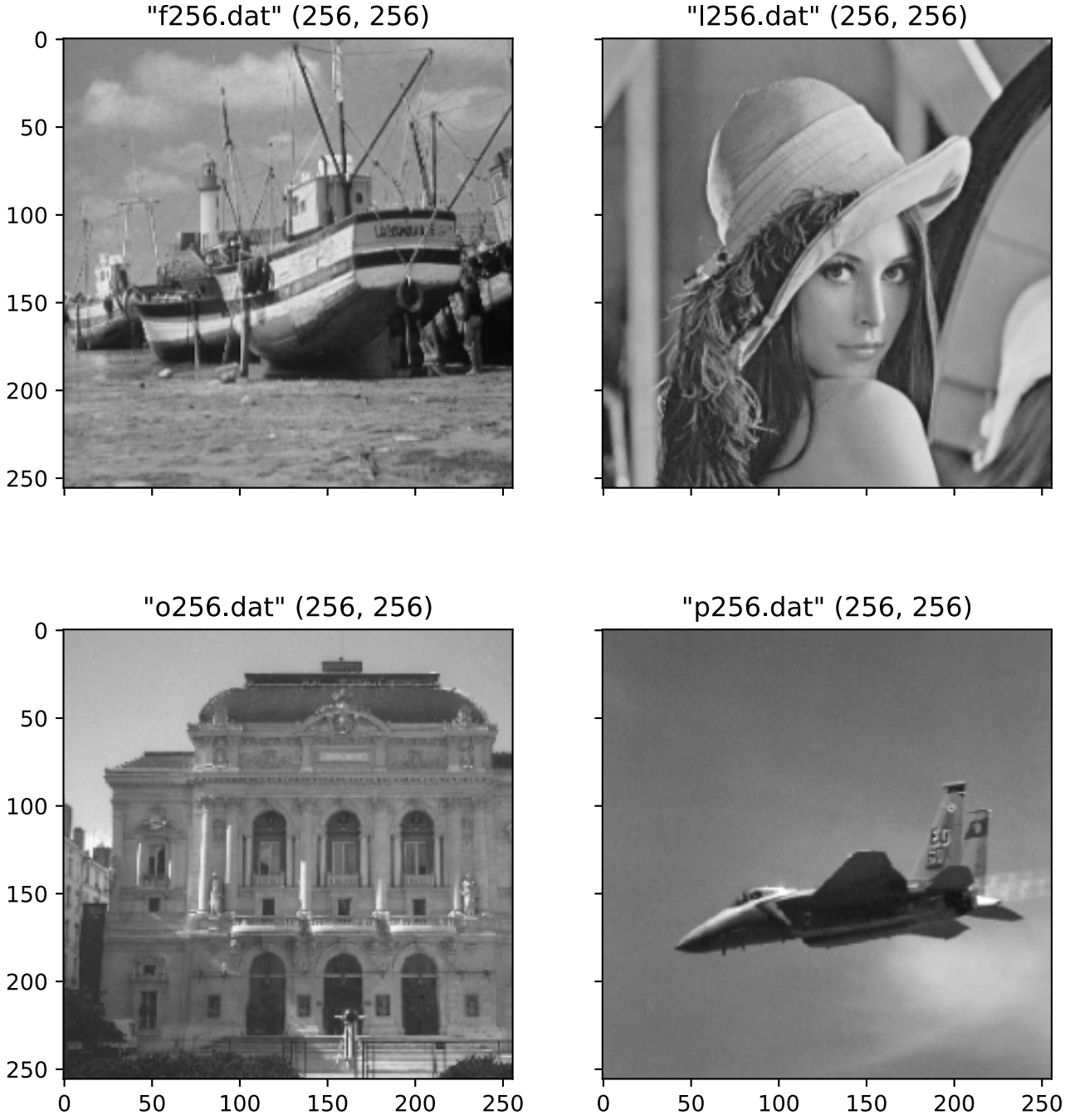
Convert images to numpy array and store in a list of tuples as (filename, np.array)

In [3]:
```
# Stores the list of dictionaries for the filename, original image, converted image/s
images = []

# Iterate for all filenames
for idx, filename in enumerate(filenames):
    # Store image pixels as uint8 2D array
    image = np.array(
        [i.strip().split() for i in open(path_inp + filename + ext_inp).readlines()],
        dtype='uint8'
    )

    # Add (filename, numpy array of image) into images list
    images.append({
        'filename': filename,
        'orig': image
    })

    # Save original image as .dat file
    np.savetxt(
        path_out_orig + ext_inp[1:] + '/' + filename + ext_inp,
        image,
        fmt=' %d',
        newline=' \n'
    )
```

Display input images

In [4]:
```
# Matrix dimensions
cols = 2
rows = -(-len(filenames) // cols)

# Create figure with rows × cols subplots
fig, axs = plt.subplots(rows, cols, dpi=80, sharex=True, sharey=True)
fig.set_size_inches(4 * cols, 4.5 * rows)

# Iterate for all images
for idx, image_dict in enumerate(images):
    filename = image_dict['filename']
    image = image_dict['orig']

    # Set subplot title as '"filename" (rows, cols)'
    axs[int(idx // cols), idx % cols].set_title('"{}" {}'.format(
        filename + ext_inp,
        image.shape
    ))
    # Add subplot to figure plot buffer
    axs[int(idx // cols), idx % cols].imshow(
        image,
        cmap='gray',
        vmin=0,
        vmax=255
    )

    # Save original image as .bmp file
    plt.imsave(
        path_out_orig + ext_out[1:] + '/' + filename + ext_out,
        image,
        cmap='gray',
```

```
        vmin=0,
        vmax=255
    )

# Hide x labels and tick labels for top plots and y ticks for right plots
for ax in axs.flat:
    ax.label_outer()

# Display the figure
plt.show()
```



Downsampling

Implement down sampling by a factor of 2 .

Apply the same effect for 2 / 3 successive times and comment on visual content.

In [5]:
```
def downsample(image, multiplier):
    '''
    Downsamples an image.

    Averages pixel values in blocks of size = multiplier

    Parameters:
        image (array-like): Input image
        multiplier(int): Block size

    Returns:
        int: Downsampled image
    '''

    down_img = np.copy(image)
    height, width = down_img.shape

    for i in range(height)[::multiplier]:
        for j in range(width)[::multiplier]:
            step = multiplier // 2

            '''
            Average all pixel value in block
            '''
            sum = 0
            for r in range(i, i + multiplier):
                for c in range(j, j + multiplier):
                    sum = sum + int(down_img[r][c])
            avg_pix = sum // (multiplier ** 2)
```

```
            '''
            Assign all pixel values in block as average value
            '''
            for r in range(i, i + multiplier):
                for c in range(j, j + multiplier):
                    down_img[r][c] = avg_pix

    return down_img
```

In [6]:

```
def plot_downsampled(key, multiplier):
    '''
    Downsamples all images and plots them.

    Parameters:
        key (str): Key in image dict to access required input images
        multiplier (int): Block size

    Returns:
        None
    '''

    cols = 2
    rows = -(-len(filenames) // cols)

    # Create figure with rows × cols subplots
    fig, axs = plt.subplots(rows, cols, dpi=80, sharex=True, sharey=True)
    fig.set_size_inches(4 * cols, 4.5 * rows)
    fig.suptitle('Downsampled: {} time ({}x)'.format(
        int(math.log(multiplier, 2)), multiplier),
        fontsize=18
    )

    # Iterate for all images
    for idx, image_dict in enumerate(images):
        filename = image_dict['filename']
        down_img = downsample(image_dict[key], multiplier)

        # Add image to dictionary
        images[idx]['down_{}x'.format(multiplier)] = down_img

        # Set subplot title
        axs[idx // cols, idx % cols].set_title('"{}"'.format(filename))
        # Add subplot to figure plot buffer
        axs[idx // cols, idx % cols].imshow(down_img, cmap='gray', vmin=0, vmax=255)

        # Save threshold image as .bmp file
        plt.imsave(
            path_out_conv + ext_out[1:] + '/' + filename + '_down_{}x'.format(multiplier) + ext_out,
            down_img,
            cmap='gray',
            vmin=0,
            vmax=255
        )

        # Save pixel values of threshold image as a 2D matrix in a .dat file
        np.savetxt(
            path_out_conv + ext_inp[1:] + '/' + filename + '_down_{}x'.format(multiplier) + ext_inp,
            down_img,
            fmt=' %d',
            newline=' \n'
        )

    # Hide x labels and tick labels for top plots and y ticks for right plots
    for ax in axs.flat:
        ax.label_outer()

    # Save and display the figure
    plt.savefig('downsampled_{}x.jpg'.format(multiplier))
    plt.show()
```

1st time (2x)

In [7]:

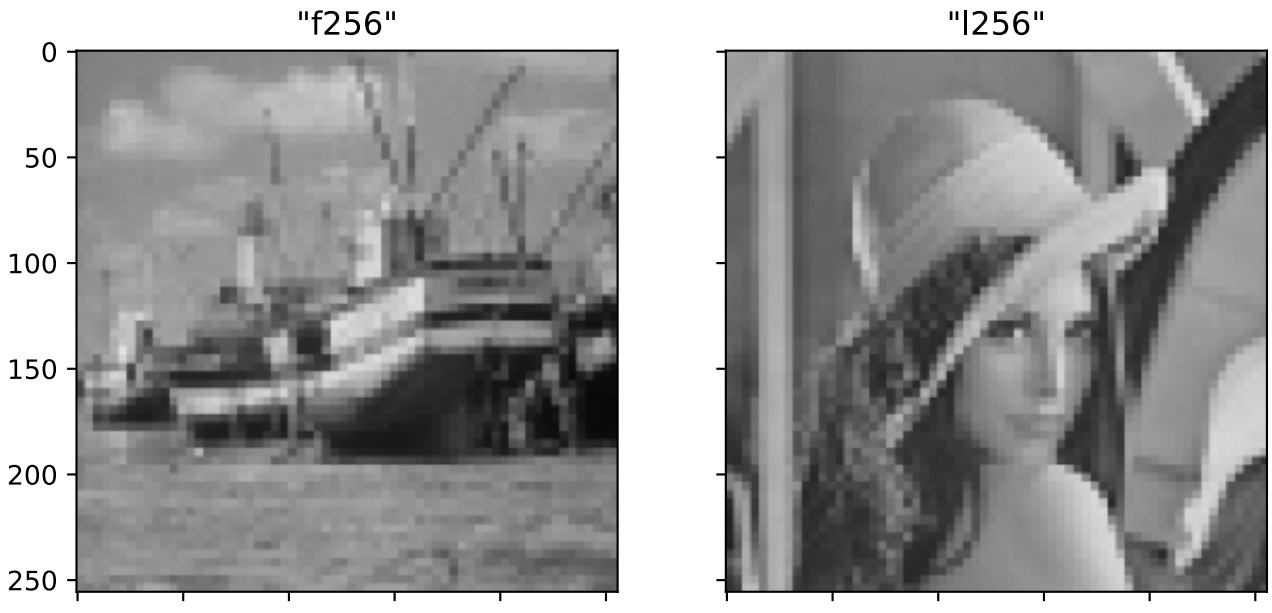
```
plot_downsampled('orig', 2)
```

Downsampled: 1 time (2x)

2nd time (4x)

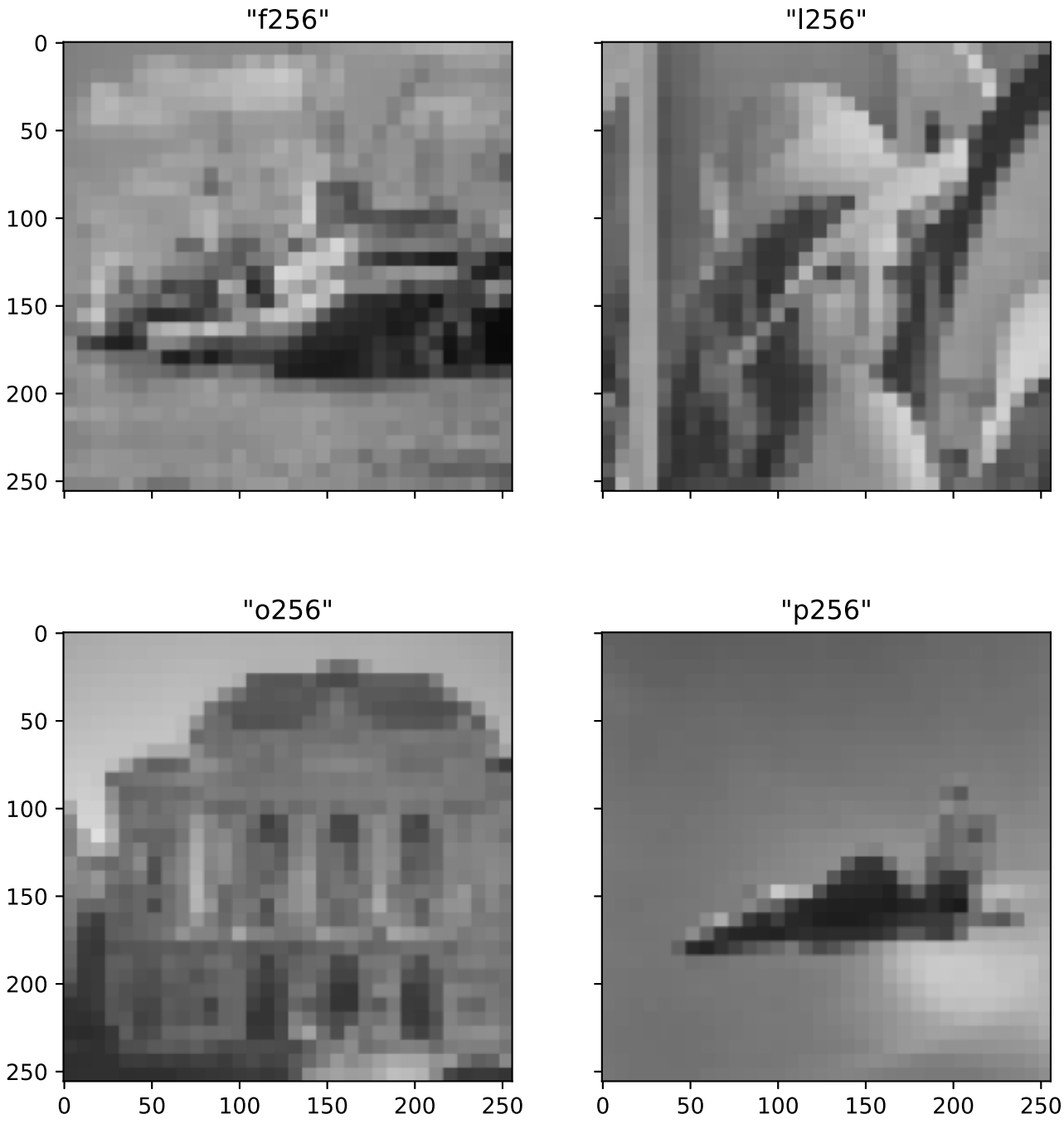
In [8]:
```
plot_downsampled('down_2x', 4)
```

Downsampled: 2 time (4x)



3rd time (8x)

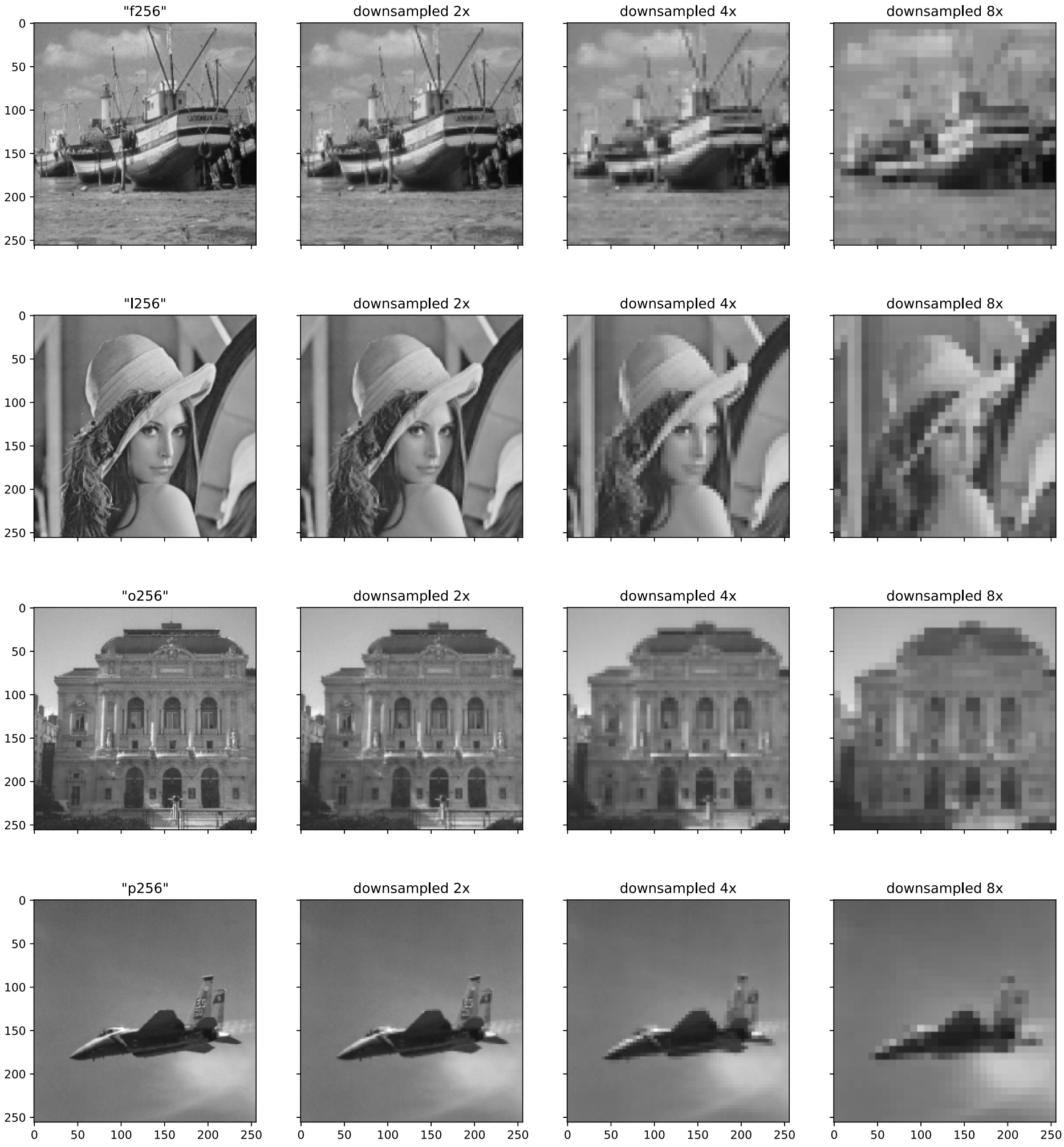
In [9]:
```
plot_downsampled('down_4x', 8)
```



Compare images

In [10]:

```
rows, cols = len(images), 4

# Create figure with rows × cols subplots
fig, axs = plt.subplots(rows, cols, dpi=80, sharex=True, sharey=True)
fig.set_size_inches(4 * cols, 4.5 * rows)
fig.suptitle("Comparing", fontsize=18)

# Iterate for all images
for idx, image_dict in enumerate(images):
    filename = image_dict['filename']
    orig = image_dict['orig']
    down_2x = image_dict['down_2x']
    down_4x = image_dict['down_4x']
    down_8x = image_dict['down_8x']

    axs[idx, 0].set_title('"{}"'.format(filename))
    axs[idx, 0].imshow(orig, cmap='gray', vmin=0, vmax=255)

    axs[idx, 1].set_title('downsampled 2x')
    axs[idx, 1].imshow(down_2x, cmap='gray', vmin=0, vmax=255)

    axs[idx, 2].set_title('downsampled 4x')
    axs[idx, 2].imshow(down_4x, cmap='gray', vmin=0, vmax=255)

    axs[idx, 3].set_title('downsampled 8x')
    axs[idx, 3].imshow(down_8x, cmap='gray', vmin=0, vmax=255)

# Hide x labels and tick labels for top plots and y ticks for right plots
for ax in axs.flat:
    ax.label_outer()

# Save and display the figure
plt.savefig('downsampled_comp.jpg')
plt.show()
```



Upsampling

Upscale the down sampled images through interpolation and comment on visual quality of the image.

In [11]:

```
def upsample(image, multiplier):
    '''
    Upsamples an image.

    Averages pixel values in blocks of size = multiplier

    Parameters:
        image (array-like): Input image
        multiplier(int): Block size

    Returns:
        int: Upsampled image
    '''

    up_img = np.copy(image)
    height, width = up_img.shape
```

```
    for i in range(height - multiplier)[::multiplier]:
        for j in range(width - multiplier)[::multiplier]:
            step = multiplier

            '''
            Average between current block and next block in all three directions.
            '''
            pix_r = (int(up_img[i][j]) + int(up_img[i][j + multiplier])) // 2
            pix_b = (int(up_img[i][j]) + int(up_img[i + multiplier][j])) // 2
            pix_d = (int(up_img[i][j]) + int(up_img[i + multiplier][j + multiplier])) // 2

            '''
            Assign right half of current block as average value between its left and
            right blocks
            '''
            for r in range(i, i + (multiplier // 2)):
                for c in range(j + (multiplier // 2), j + multiplier):
                    up_img[r][c] = pix_r

            '''
            Assign bottom half of current block as average value between its top and
            bottom blocks
            '''
            for r in range(i + (multiplier // 2), i + multiplier):
                for c in range(j, j + (multiplier // 2)):
                    up_img[r][c] = pix_b

            '''
            Assign corner half of current block as average value between its left and
            right diagonal blocks
            '''
            for r in range(i + (multiplier // 2), i + multiplier):
                for c in range(j + (multiplier // 2), j + multiplier):
                    up_img[r][c] = pix_d

    return up_img
```

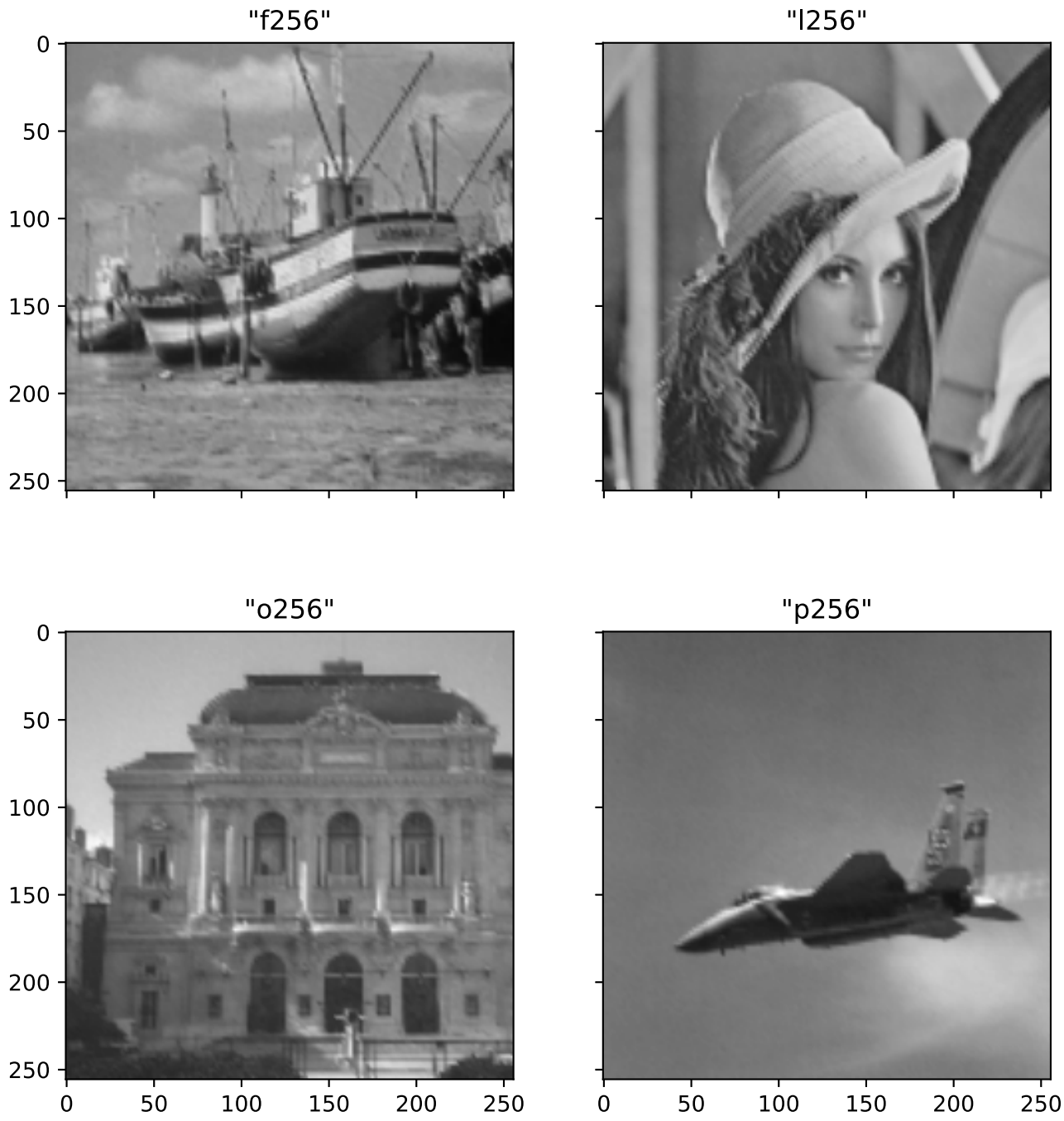
In [12]:

```
def plot_upsampled(key, multiplier):
    '''
    Upsamples all images and plots them.

    Parameters:
        key (str): Key in image dict to access required input images
        multiplier (int): Block size

    Returns:
        None
    '''

    cols = 2
    rows = -(-len(filenames) // cols)

    # Create figure with rows × cols subplots
    fig, axs = plt.subplots(rows, cols, dpi=80, sharex=True, sharey=True)
    fig.set_size_inches(4 * cols, 4.5 * rows)
    fig.suptitle('Upsampled: {} time ({}x)'.format(
        int(math.log(multiplier, 2)), multiplier),
        fontsize=18
    )

    # Iterate for all images
    for idx, image_dict in enumerate(images):
        filename = image_dict['filename']

        for i in range(int(math.log(multiplier, 2))):
            up_img = upsample(image_dict[key], multiplier)
            # Add image to dictionary
            images[idx]['up_{}x'.format(multiplier)] = up_img

        # Set subplot title
        axs[idx // cols, idx % cols].set_title('"{}"'.format(filename))
        # Add subplot to figure plot buffer
        axs[idx // cols, idx % cols].imshow(up_img, cmap='gray', vmin=0, vmax=255)

        # Save threshold image as .bmp file
        plt.imsave(
            path_out_conv + ext_out[1:] + '/' + filename + '_up_{}x'.format(multiplier) + ext_out,
            up_img,
            cmap='gray',
            vmin=0,
            vmax=255
        )

        # Save pixel values of threshold image as a 2D matrix in a .dat file
        np.savetxt(
            path_out_conv + ext_inp[1:] + '/' + filename + '_up_{}x'.format(multiplier) + ext_inp,
            up_img,
            fmt=' %d',
            newline=' \n'
        )

    # Hide x labels and tick labels for top plots and y ticks for right plots
```

```
    for ax in axs.flat:
        ax.label_outer()

    # Save and display the figure
    plt.savefig('upsampled_{}x.jpg'.format(multiplier))
    plt.show()
```

1 time (2x)

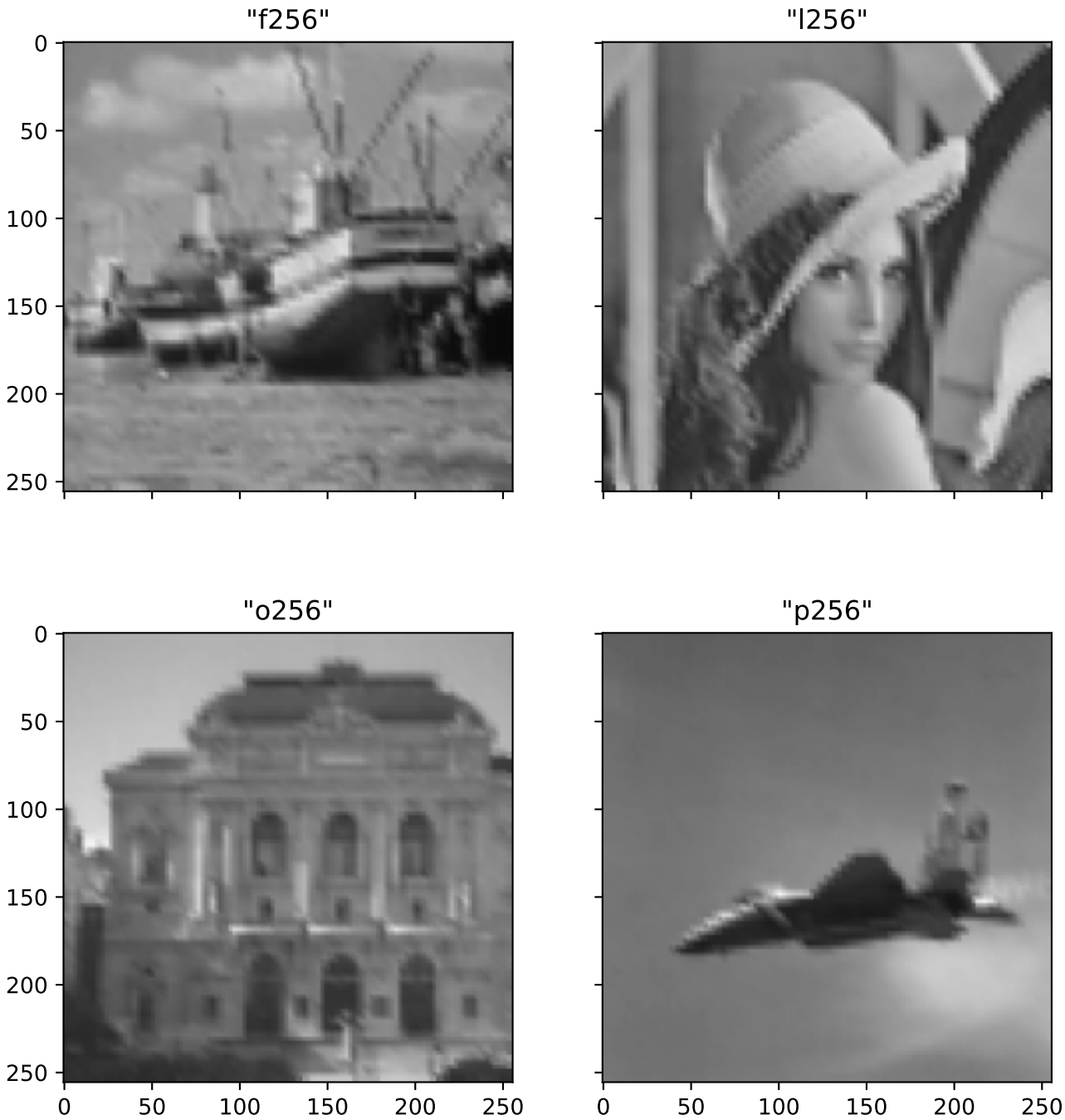
In [13]:
```
plot_upsampled('down_2x', 2)
```



2 times (4x)

In [14]:
```
plot_upsampled('down_4x', 4)
```

Upsampled: 2 time (4x)



3 times (8x)

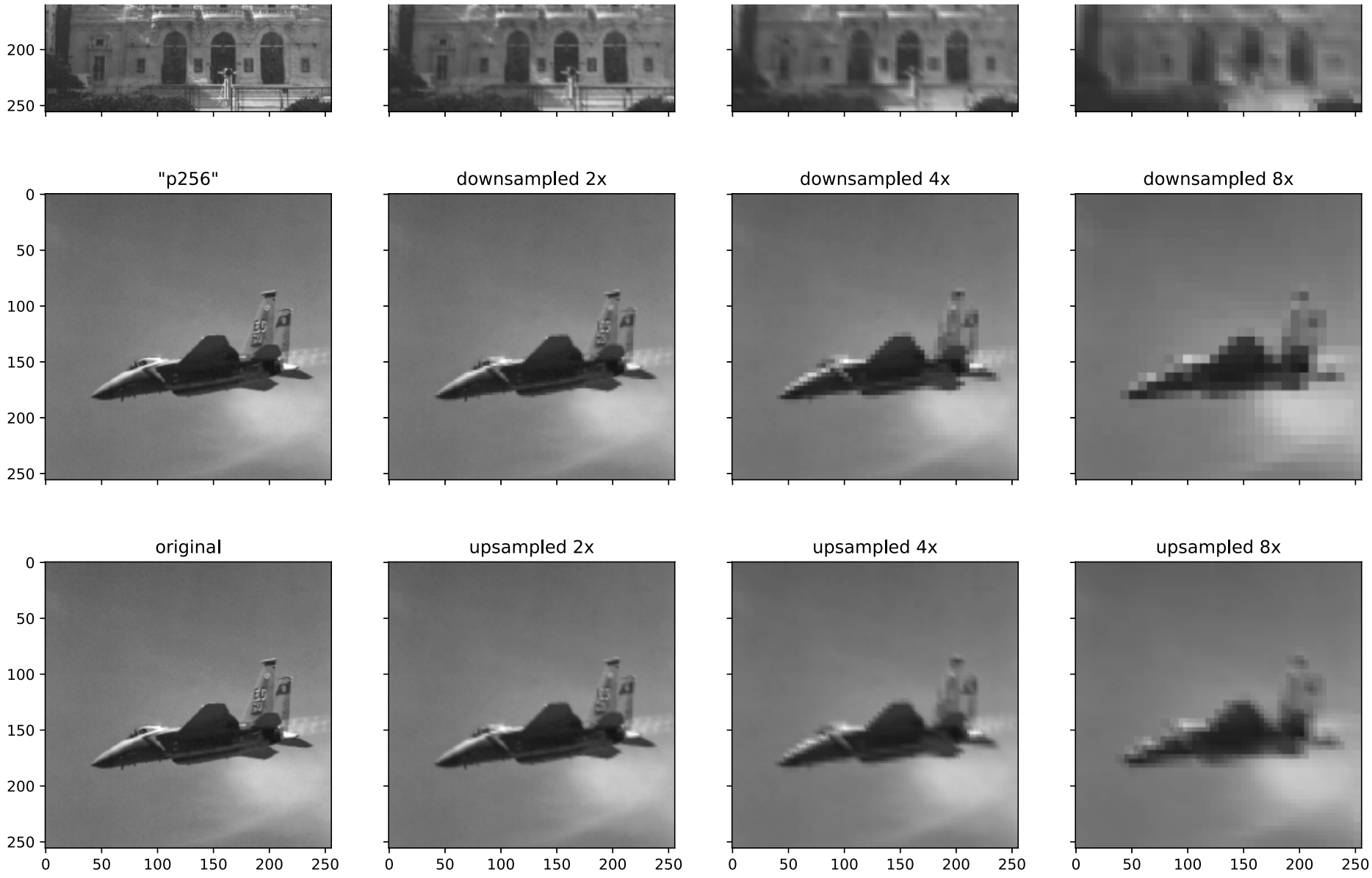
In [15]:
```
plot_upsampled('down_8x', 8)
```

Compare images

In [16]:

```
rows, cols = len(images) * 2, 4

# Create figure with rows × cols subplots
fig, axs = plt.subplots(rows, cols, dpi=80, sharex=True, sharey=True)
fig.set_size_inches(4 * cols, 4.5 * rows)

# Iterate for all images
for idx, image_dict in enumerate(images):
    filename = image_dict['filename']
    orig = image_dict['orig']
    down_2x = image_dict['down_2x']
    down_4x = image_dict['down_4x']
    down_8x = image_dict['down_8x']
    up_2x = image_dict['up_2x']
    up_4x = image_dict['up_4x']
    up_8x = image_dict['up_8x']

    axs[2 * idx, 0].set_title('"{}"'.format(filename))
    axs[2 * idx, 0].imshow(orig, cmap='gray', vmin=0, vmax=255)

    axs[2 * idx, 1].set_title('downsampled 2x')
    axs[2 * idx, 1].imshow(down_2x, cmap='gray', vmin=0, vmax=255)

    axs[2 * idx, 2].set_title('downsampled 4x')
    axs[2 * idx, 2].imshow(down_4x, cmap='gray', vmin=0, vmax=255)

    axs[2 * idx, 3].set_title('downsampled 8x')
    axs[2 * idx, 3].imshow(down_8x, cmap='gray', vmin=0, vmax=255)

    axs[2 * idx + 1, 0].set_title('original')
    axs[2 * idx + 1, 0].imshow(orig, cmap='gray', vmin=0, vmax=255)

    axs[2 * idx + 1, 1].set_title('upsampled 2x')
    axs[2 * idx + 1, 1].imshow(up_2x, cmap='gray', vmin=0, vmax=255)

    axs[2 * idx + 1, 2].set_title('upsampled 4x')
    axs[2 * idx + 1, 2].imshow(up_4x, cmap='gray', vmin=0, vmax=255)

    axs[2 * idx + 1, 3].set_title('upsampled 8x')
    axs[2 * idx + 1, 3].imshow(up_8x, cmap='gray', vmin=0, vmax=255)

# Hide x labels and tick labels for top plots and y ticks for right plots
```

```
for ax in axs.flat:
    ax.label_outer()

# Save and display the figure
plt.savefig('upsampled_comp.jpg')
plt.show()
```



Resource

GitHub repository: `Image Processing and Pattern Recognition - Anindya Kundu (meganindya)`